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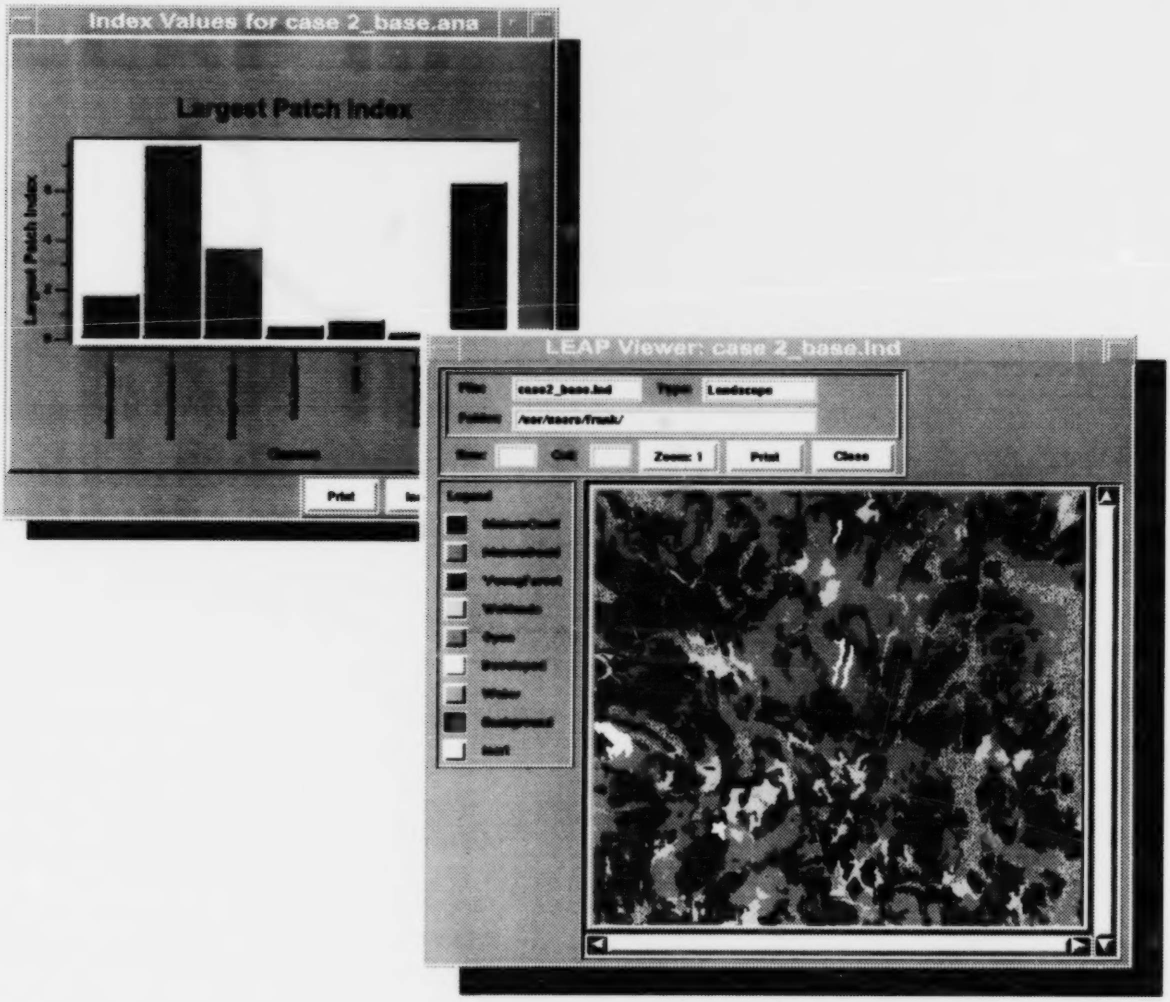
LEAP II:

A Landscape Ecological Analysis Package for Land Use Planners and Managers



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LEAP II: A Landscape Ecological Analysis Package for Land Use Planners and Managers

by

Ajith H. Perera
David J.B. Baldwin
Frank Schnekenburger

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Ontario Ministry of Natural Resources
Ontario Forest Research Institute
1235 Queen Street East
Sault Ste. Marie, Ontario
Canada P6A 2E5

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Ministry of Natural Resources
Ontario Forest Research Institute
1235 Queen Street East
Sault Ste. Marie, ON
Canada P6A 2E5

Telephone: (705) 946-2981
Fax: (705) 946-2030
E-mail: ofriin@gov.on.ca

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Abstract

The Landscape Ecological Analysis Package Version 2.0 (LEAP II) is a spatial decision-support tool for forest and other land managers. It is designed for the UNIX platform, partly based on FRAGSTATS raster computational routines. LEAP II lets the user explore, monitor, and assess a landscape for its ecological status once the management objectives are in place. The ecological concepts analyzed include patchiness, shape, isolation, edge, interior, connectivity, and material/organism movement. LEAP II has 3 user levels to allow varying degrees of analysis sophistication. This guide introduces the user to landscape ecological concepts, describes how to install the software, presents several case studies, and provides step-by-step instructions for using LEAP II.

Keywords: landscape ecology, landscape structure, landscape metrics, spatial patterns, forest landscapes, Ontario, FRAGSTATS, land cover assessment, biodiversity

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CHAPTER 1

Introduction

Good forest management requires that managers set definitive goals and explicit objectives, learn as they do, and adapt the management process progressively (Walters and Holling 1990). It also requires setting quantifiable targets, monitoring/tracking the changes, and evaluating the attainability of goals. This process is relatively simple with singular forest management objectives that are readily quantifiable, such as timber yield or the population of a bird species. However, abstract ecological objectives (e.g., biodiversity) and the goal of ecological sustainability are more complex and nebulous. New tools such as the ***Landscape Ecological Analysis Package Version 2.0 (LEAP II)*** can help to simplify, quantify, and assess these goals and objectives.

1.1 What Is LEAP II?

LEAP II is a simple raster-based geographic information system (GIS) tool designed to support forest management decisions. This tool uses spatial data to analyze the land cover patterns in a forested landscape and summarizes the information using indices to assess overall ecological condition. To increase its versatility, LEAP II was designed to be generic, compelling the end user to define its specific application (e.g., scale, land cover classification) and to think explicitly while using the program.

LEAP II is the revised and public domain version of LEAP, which evolved from the landscape analysis tools LDA (Perera and Schnekenburger 1993) and FRAGSTATS (McGarigal and Marks 1995). LEAP II is more user friendly, convenient, simple, and interactive, and it uses the raster version of FRAGSTATS in computation routines. In addition, this tool contains a spatial spread analysis routine and an extensive graphic user interface. In essence, LEAP II is an analytical tool that can be used with other spatial decision-support systems (DSS) such as landscape generators (e.g., fire regime simulator, forest harvest planner).

1.2 Why Use LEAP II?

LEAP II can assist forest managers with some fundamental decisionmaking steps:

- ***Exploring***: LEAP II can provide an ecological overview of a given landscape from many perspectives (e.g., fragmentation, edge content, spatial geometry, and connectivity). This overview provides the initial *ecological status* of a landscape prior to designing a management strategy or setting reference points for long-term evaluations.
- ***Monitoring***: After a management or a policy option is implemented in a given landscape, LEAP II can be used to track temporal trends in ecological criteria (e.g., edge content, degree of interspersion) at certain time steps.
- ***Assessing***: Because LEAP II simplifies and quantifies concepts such as fragmentation and biodiversity, it provides a useful means of assessing results of management and policy in either time or space. Spatial simulations of policy and management options using LEAP II enable forest managers to assess the ecological status of the landscape comparatively.

In Ontario, recent legislative changes (Aird 1996) require forest managers to evaluate forest landscape conditions and report the ensuing changes every 5 years (OMNR 1996). They will be able to use LEAP II to assess these conditions as well as some indicators of forest sustainability criteria, as defined by the Canadian Council of Forest Ministers (CCFM 1995). For detailed examples of LEAP II use, see Chapters 5-8.

1.3 Who Should Use LEAP II?

LEAP II was designed primarily for forest managers, who plan and manage forests at the planning-unit level. However, any policymaker, planner, or manager interested in landscape ecology will find it useful. The scale of use ranges from regional to forest planning unit. The user needs a basic understanding of computer systems, GIS, and spatial data to *prepare the data* but not to run LEAP II and interpret the output. The user must also have a good understanding of scale, resolution of data, land cover classes, landscape ecological issues, and the validity of comparisons (for more on the wise use and misuse of LEAP II, see Chapter 4). Most importantly, the user must have *a priori* objectives that can be related to LEAP II output. In other words, LEAP II requires the user to pose the contextual questions of why, when, and what explicitly.

LEAP II has 3 user levels. At the ***basic level***, the user can analyze landscapes through a minimal set of indices, with no provision for spread analyses. This level is suitable for those who run landscape analyses for pre-determined monitoring purposes. The ***intermediate level***, which has a limited set of indices with access to spread analyses, is suitable for those who wish to explore the ecological status of the landscape in a heuristic fashion, in addition to monitoring. The ***advanced level*** allows the user to access the full suite of indices, all statistical estimators of the indices for comparison, and spread analyses. Therefore, it is suitable for those well versed in ecological indices and for those who need statistical rigour in comparisons of time steps or spatial simulations of landscapes. Even researchers who have their own algorithms to compute landscape ecological indices may find LEAP II useful due to its user-friendliness and simplicity. What's more, educators in landscape ecology, forest and wildlife management, and environmental policy can use LEAP II to illustrate principles of landscape ecology and management.

1.4 What Do You Need to Use LEAP II?

1.4.1 System Requirements

LEAP currently runs on Unix-based systems. It is available for the Digital© Unix and the Sun© Solaris. However, it can be easily ported to other versions of Unix. Installation requires approximately 27 megabytes of disk space. Additional disk space is required for datasets, output files, and temporary work files. These requirements will vary with the size and number of datasets and the type of analysis.

LEAP can be installed separately on several computers or installed on a single server and accessed from other Unix terminals on a local area network. In the latter case, it can be run on networked PCs that have an X-server emulator (e.g., Exceed).

1.4.2 Data Requirements

Base data input files for LEAP II must be 16-bit or 32-bit binary raster images, with a corresponding ASCII text data attribute file (for more details, see Appendix II). ***LEAP Builder*** can import ARC/INFO coverages into LEAP II and convert them to base datasets.

1.4.3 Output Requirements

LEAP can print text to any networked printer and images to any networked postscript printer or plotter. In addition, output can be saved to text and postscript files for viewing or printing using other software products.

CHAPTER 2

Landscape Ecological Concepts and LEAP II

Understanding landscape ecology concepts is critical to avoiding ambiguity and misinterpretation, especially with respect to terminology. This chapter provides a brief review of landscape ecology concepts. For more in-depth information, see a general landscape ecology text such as Forman and Godron (1986), Allen and Hoekstra (1992), or Forman (1995).

2.1 Quantifying Landscape Patterns

The basic tenet of landscape ecology is that the function and processes of a landscape are primarily due to the spatial patterns of its components (Turner 1989). Since the origin of landscape ecology in the 1930s, researchers have focussed on the spatial patterns of component ecosystems (Forman and Godron 1986). Quantifying spatio-temporal patterns of landscapes appears to be the most popular topic among researchers (e.g., Krummel *et al* 1987, O'Neil *et al* 1988, Iverson 1989, Turner and Gardener 1991, Gustafson and Parker 1992, Li and Reynolds 1993, Hunsaker *et al* 1994, Benson and MacKenzie 1995, Haines-Young and Chopping 1996, Keitt *et al* 1997, Gustafson *in press*). Parallel progress in GIS, spatial statistics, and fractal geometry has resulted in many indices that quantify landscape patterns. While these metrics are becoming increasingly esoteric, the concepts they explore remain simple.

The *consequences* of landscape spatial patterns are less well documented. Studies linking landscape patterns to processes are more recent and relatively uncommon (e.g., Gustafson and Crow 1994, McGarigal and McComb 1995, Baker 1996, Otto 1996, and Ripple *et al* 1997). Therefore in practice, linking landscape patterns to biotic processes (e.g., habitat supply, population dynamics, and migration) and abiotic processes (e.g., wildfires) remains a logical extrapolation of simple ecological theory.

2.2 Basic Landscape Ecology Concepts

A landscape's spatial pattern is derived from the spatial attributes of its components or ***patches.*** Defining a ***landscape*** and its patches is fundamental to landscape ecology. Because landscapes and patches are organism based (e.g., the landscape perceived by moose is not necessarily the landscape perceived by marten), there are no "right" or "wrong" landscapes or patches. In fact, they exist in all sizes and shapes and at all scales. However, there are *appropriate* landscapes and patches, one that are pertinent to the ecological phenomenon or the management objective (for an excellent discussion on this topic, see Allen and Hoekstra 1992). Therefore, the user must define landscapes and patches based on the most pertinent question at hand. For example, in forest management, a working definition of a landscape could be a collection of forest stands. The boundaries of such a surrogate landscape could be an ecological unit (preferable) such as a landform type, eco-district, or watershed or an administrative unit such as a forest management unit (less preferable).

In LEAP II terminology, a *landscape* refers to the effective extent of the land analyzed. LEAP II expects the data to be in a square matrix; however, the landscape can be irregular as long as the boundaries do not extend beyond the matrix.

Defining *patches,* arguably more critical than landscape definition, is simple yet confusing. It is simple because a patch is an intuitive unit, and some patches (e.g., forest stand, wetland) are more spatially distinct than landscapes. It is confusing because the patches are scale dependent; they depend on the spatial resolution of the data. Since LEAP II analyzes landscapes using raster data, the resolution of the input data determines the scale of the analysis. This critical determination will affect not only the efficiency and speed of the analysis but also the results and their ecological interpretation.

In Ontario forest landscape analyses, a reasonable data resolution (cell size) ranges from 1 to 4 ha. However, there are no universal rules for selecting an appropriate data resolution. Local conditions, the management or analytical objective, and the available data all influence this decision. As landscape pattern analyses mature, general guidelines for data resolution will develop. The patches that form the landscape are themselves composed of raster data points (pixels). Each pixel is square and has a dimension that is determined by the resolution of data. For example, at 1 ha resolution, a pixel is 100 m x 100 m, and the spatial description of patches and the analyses are conducted in 100 m steps. The patches are defined as groups of 1 ha pixels, with the smallest possible patch size being 1 ha. Therefore, in a given landscape, the patches and spatial patterns recognizable at 1 ha resolution may not be those seen at 10 ha resolution.

The ***classes*** are the patch types or the unique types of pixels. Assigning these classes is the most important decision a LEAP II user will make. This step relates directly to the objective and cannot be prescribed universally. If the objective is moose management, the patch classes should relate to moose habitat, and they may not be relevant to marten, forest fire or timber supply. Furthermore, these classes may overlap spatially, making a spatial patch definition impossible. Two practical solutions: Define the classes and patches for each objective (e.g., moose habitat, marten habitat) individually, or use a more generic patch definition (e.g., tree species composition) that has wider application.

LEAP II provides an ***inert class*** option that can assign null values to some pixels to exclude them from the analysis (e.g., to water bodies that may not exert an edge effect on a terrestrial interior species).

Once the patches and the landscape are appropriately defined, their size, shape, and arrangement in space determine the landscape ***structure***. In LEAP II, a landscape's spatial structure is represented in the following dimensions:

- ***Patchiness*** refers to the relative contiguity (clumping) of a landscape. A *contiguous* landscape is less patchy than a dispersed or a "broken up" landscape. A *patchy* landscape is composed of many small patches and a few large patches and has less contiguity.
- ***Shape*** refers to the relative complexity of patch geometry. A *complex* patch has an amoebae-like shape; a *simple* one is more circular or square. A landscape full of complex patches will have a complex internal geometry.
- ***Isolation*** refers to the distance between similar patches. As this distance increases, patches are considered more isolated.

Based on user interpretation of the ecological questions at hand, these dimensions can be extended to the following value-based concepts:

- ***Edge*** is the ecotone between a patch and its surrounding area. In its simplest form, the edge is the perimeter of a patch. Depending on the objective, the user may add value to this perimeter in the form of ***edge contrast*** and ***buffer width***.
- ***Interior*** is the core area of a patch after accounting for the width of the ecotone or ***buffer***. This measurement is also value-based, depending on the objective.
- ***Fragmentation*** refers to the relative patchiness, isolation, and simplicity of shapes.

LEAP II can also examine the following compositional characteristics of a landscape, which together indicate its compositional diversity:

- ***Richness*** is the number of classes (patch types) that compose the landscape. A relatively *rich* landscape is composed of more classes than one that is *less rich*.
- ***Evenness*** describes how evenly the area is distributed among the classes present on the landscape. Thus a *more even* landscape has classes that occupy similar proportions of the area, with no dominant classes. A *less even* landscape has a few dominant classes, with the others occupying small areas of the landscape.

- ***Heterogeneity*** [1] combines richness and evenness and reflects the overall diversity of the landscape. A more heterogeneous landscape will have a high degree of richness and evenness and therefore will be more diverse than a landscape with low richness and evenness values.

Finally, LEAP II explores the degree of *connectivity* between patches (a corridor between 2 patches or a multi-point linkage among many patches), which can be derived based on species (e.g., black bear forage routes) or process (e.g., fire spread).

---

[1] *We follow the narrower definition of* heterogeneity *(Peet 1974), as opposed to the broader one (Li and Reynolds 1995).*

Chapter 3

LEAP II Landscape Indices

LEAP II provides a suite of structural indices and compositional indices and a spread analysis method of assessing connectivity. These measurements are categorized in many ways. LEAP II allows the user to analyze the landscape as a whole (***landscape level***), by its component classes (***class level***), or 1 patch at a time (***patch level***). Some indices are relevant only at the landscape level (e.g., ***richness, evenness, heterogeneity***, and ***interspersion***), class level (e.g., ***core area dominance***) or patch level (e.g., ***edge contrast***), thus the indices are grouped by their appropriateness to the scale hierarchy. The structural indices are sorted by the ecological concept they explore: patchiness, shape, isolation, edge, and interior (Table 1). Similarly, the compositional indices are categorized by richness, evenness, and heterogeneity (Table 2).

This chapter describes the various indices and their function; however, it does not provide the mathematical formulae and historical evolution of these indices in ecology (see the excellent and authoritative account by McGarigal and Marks (1995) in their description of FRAGSTATS).

Table 1. LEAP II landscape structural indices, as computed by FRAGSTATS (McGarigal and Marks 1995) routines.

Concept	Index	Units/Value Range	Abbr.	Hierarchical Level	Reference
Patchiness	Largest patch index	(%) 0 to 100	LPI	Landscape, class	McGarigal and Marks (1995)
	Number of patches	(number) 0 < to ∞	NP	Landscape, class	McGarigal and Marks (1995)
	Patch density	(#/100 ha) 0 < to ∞	PD	Landscape, class	McGarigal and Marks (1995)
	Mean patch size	(ha) 0 < to ∞	MPS	Landscape, class	McGarigal and Marks (1995)
	Patch size standard deviation	(ha) 0 < to ∞	PSSD	Landscape, class	McGarigal and Marks (1995)
	Patch size coefficient of variation	(%) 0 to 100	PSCV	Landscape, class	McGarigal and Marks (1995)
	Contagion index	(%) 0 to 100	CONTAG	Landscape	Li and Reynolds (1993)
Shape	Shape index	(none) 1≤ to ∞	SHAPE	Patch	Patton (1975)
	Mean shape index	(none) 1≤ to ∞	MSI	Landscape, class	McGarigal and Marks (1995), after Patton (1975)
	Area-weighted mean shape index	(none) 1≤ to ∞	AWMSI	Landscape, class	McGarigal and Marks (1995), after Patton (1975)
	Patch fractal dimension	(none) 1 ≤ to 2	FRACT	Patch	Mandelbrot (1977)

Table continues on next page.

Concept	Index	Units/Value Range	Abbr.	Hierarchical Level	Reference
	Mean patch fractal dimension	(none) 1 ≤ to 2	MPFD	Landscape, class	McGarigal and Marks (1995), after Mandelbrot (1977)
	Area-weighted mean patch fractal dimension	(none) 1 ≤ to 2	AWMPFD	Landscape, class	McGarigal and Marks (1995), after Mandelbrot (1977)
	Fractal dimension	(none) 1 ≤ to 2	DLFD	Landscape, class	Burrough (1986)
Isolation	Nearest-neighbour distance	(m) 0 < to ∞	NEAR	Patch	McGarigal and Marks (1995)
	Mean nearest-neighbour distance	(m) 0 < to ∞	MNN	Landscape, class	McGarigal and Marks (1995)
	Nearest-neighbour standard deviation	(m) 0 < to ∞	NNSD	Landscape, class	McGarigal and Marks (1995)
	Nearest-neighbour coefficient of variation	(%) 0 to 100	NNCV	Landscape, class	McGarigal and Marks (1995)
	Proximity index	(none) 0 ≤ to ∞	PROXIM	Patch	Gustafson and Parker (1994)
	Mean proximity index	(none) 0 ≤ to ∞	MPI	Landscape, class	Gustafson and Parker (1994)
	Interspersion index	(%) 0 to 100	INTIN	Landscape, class	McGarigal and Marks (1995)
Edge	Edge	(m) 0 < to ∞	Edge	Patch	McGarigal and Marks (1995)
	Total edge	(m) 0 < to ∞	Total edge	Landscape, class	McGarigal and Marks (1995)
	Edge density	(m/ha) 0 < to ∞	Edge den	Landscape, class	McGarigal and Marks (1995)
	Edge contrast index	(%) 0 to 100	ECI	Patch	McGarigal and Marks (1995)
	Contrast-weighted edge density	(m/ha) 0 < to ∞	CWED	Landscape, class	McGarigal and Marks (1995
	Total edge contrast index	(%) 0 to 100	TECI	Landscape, class	McGarigal and Marks (1995)
	Mean edge contrast index	(%) 0 to 100	MECI	Landscape, class	McGarigal and Marks (1995)
	Area-weighted mean edge contrast index	(%) 0 to 100	AWMECI	Landscape, class	McGarigal and Marks (1995)
Interior	Core area	(ha) 0 < to ∞	CORE	Patch	McGarigal and Marks (1995)
	Total core area	(ha) 0 < to ∞	Total CA	Landscape, class	McGarigal and Marks (1995)
	Core area (%)	(%) 0 to 100	CA %	Patch	McGarigal and Marks (1995)

Table continues on next page.

Concept	Index	Units/Value Range	Abbr.	Hierarchical Level	Reference
Interior *(Continued)*	Total core area	(ha) 0 < to ∞	Total CA	Landscape, class	McGarigal and Marks (1995)
	Core area (%)	(%) 0 to 100	CA %	Patch	McGarigal and Marks (1995)
	Core area dominance index	(%) 0 to 100	C%Land	Class	McGarigal and Marks (1995)
	Total core area index	(%) 0 to 100	TCA %	Landscape, class	McGarigal and Marks (1995)
	Mean core area index	(%) 0 to 100	MCA %	Landscape, class	McGarigal and Marks (1995)
	Number of core areas	(none) 0 < to ∞	NCORE	Patch	McGarigal and Marks (1995)
	Number of core areas	(none) 0 < to ∞	Num CA	Landscape, class	McGarigal and Marks (1995)
	Core area density	(#/100 ha) 0 < to ∞	CAD	Landscape, class	McGarigal and Marks (1995)
	Mean core area per patch	(ha) 0 < to ∞	MCA 1	Landscape, class	McGarigal and Marks (1995)
	Patch core area standard deviation	(ha) 0 < to ∞	CASD1	Landscape, class	McGarigal and Marks (1995)
	Patch core area coefficient of variation	(%) 0 to 100	CACV1	Landscape, class	McGarigal and Marks (1995)
	Mean area per disjunct core area	(ha) 0 < to ∞	MCA2	Landscape, class	McGarigal and Marks (1995)
	Disjunct core area standard deviation	(ha) 0 < to ∞	CASD2	Landscape, class	McGarigal and Marks (1995)
	Disjunct core area coefficient of variation	(%) 0 to 100	CACV2	Landscape, class	McGarigal and Marks (1995)

Table 2. LEAP II landscape compositional indices, as computed by FRAGSTATS (McGarigal and Marks 1995) routines.

Concept	Index	Units/Value Range	Hierarchical Level	Reference
Richness	Class richness	(none) 1≤ to ∞	Landscape	McGarigal and Marks (1995)
	Class richness density	(#/100 ha) 0 < to ∞	Landscape	McGarigal and Marks (1995)
Evenness	Shannon evenness index	(none) 0 ≤ to < 1	Landscape	Shannon and Weaver (1949)
	Simpson evenness index	(none) 0 ≤ to < 1	Landscape	Simpson (1949)
	Modified Simpson evenness index	(none) 0 ≤ to < 1	Landscape	Pielou (1975)
Heterogeneity	Shannon diversity index	(none) 0 ≤ to ∞	Landscape	Shannon and Weaver (1949)
	Simpson diversity index	(none) 0 ≤ to < 1	Landscape	Simpson (1949)
	Modified Simpson diversity index	(none) 0≤ to ∞	Landscape	Pielou (1975)

For the most part, LEAP II uses the terminology of McGarigal and Marks (1995). At the intermediate and advanced user levels, minor changes were made to the index terminology and abbreviations (Tables 1 and 2). At the basic level, the terminology was changed significantly to make the index names more intuitive (Table 3). However, these changes are relevant only if the user wants to use *both* LEAP II and FRAGSTATS or to switch back and forth between the basic and other levels of LEAP II. Since LEAP II uses the raster version of FRAGSTATS as the computing engine, the output indices of LEAP II and the raster version of FRAGSTATS should be identical.

Table 3. Changes to FRAGSTATS (McGarigal and Marks 1995) terminology at LEAP II basic user level.

FRAGSTATS/LEAP II Intermediate/ Advanced Terminology	LEAP II Basic User Terminology
Core area	Forest interior
Total core area density	Forest interior density
Total core area index	Forest interior index
Mean nearest-neighbour distance	Proximity (distance)
Proximity index	Proximity (area)
Shannon evenness index	Evenness (Shannon)
Simpson evenness index	Evenness (Simpson)
Shannon heterogeneity index	Heterogeneity (Shannon)
Simpson heterogeneity index	Heterogeneity (Simpson)

3.1 Landscape Structural Indices

3.1.1 Patchiness Indices

Patchiness can be evaluated at landscape and/or class levels. Inferences are valid and strong *only if* a benchmark is available for reference (e.g., the intrinsic patchiness as determined by a combination of environment and natural disturbance or long-term observations). In the absence of a logically defensible benchmark, the inferences will remain postulations or hypotheses. Patchiness indices are as follows:

- ***Largest patch index*** computes the percentage of the total landscape area occupied by the largest patch in the landscape or a given class. It is useful to indicate the largest single patch of each class and the relative contribution of each to the landscape. For example, a very large landscape with few classes can be deemed patchy if the largest patch index for the landscape and the classes remains small.
- The simple ***number of patches*** in the landscape and in each class indicates the *relative* degree of patchiness. All *patchy* landscapes/classes will have a high number of patches, but not all landscapes/classes with high number of patches are considered patchy.
- The ***patch density*** standardizes the patchiness by dividing the number of patches by the landscape or class area. It is useful for comparing landscapes or classes with different spatial extent.
- ***Mean patch size*** is a similar index, derived by dividing the landscape/class area by the number of patches.
- The ***patch size standard deviation*** is computed as the sample standard deviation of the random variable (i.e., patch size).
- The ***patch size coefficient of variation*** indicates the relative variability of patch sizes around their mean. Both this and the previous indices permit the user to make statistically valid expressions and comparisons of the mean patch size.
- The ***contagion index*** (Li and Reynolds 1993) measures the *clumping* (lack of patchiness) or *dispersion and interspersion* (patchiness) in the landscape. It is a true landscape-level index (abstracted from patch and class constituents) that is computed based on the probabilities of a pixel belonging to a class and its neighbours belonging to another class. Therefore, it is a confounded index, estimating patchiness from 2 dimensions: *interspersion* (see the description of *interspersion index* in Section 3.1.3) and *contiguity* or *clumping*. Generally, higher contagion values indicate less patchiness (few smaller patches) and less intermixing (less isolation). Lower contagion values may indicate a "broken-up" or a fragmented landscape.

3.1.2 Shape Indices

Shape indices fall into 2 categories:

- The ***shape index*** indicates the amount of relative *interior* of a given patch. Shape index is computed as a simple perimeter to area ratio, standardized for a square patch (Patton 1975). Higher shape index values (>1) indicate that a patch has more perimeter per unit area, or conversely, that it has less interior. Shape index values increase until a patch is a thin strip, with no interior. From this, ***mean shape index*** values can be computed for the landscape or for each class (sum of all shape indices divided by the number of patches). To avoid biases by the necessarily square shapes of smaller patches, and to emphasize the significance of large patches, McGarigal and Marks (1995) introduced the ***area-weighted mean shape index***. This index is computed by positively weighting each shape index by the area of the patch.

- The second aspect of shape measurement deals with relative *complexity* of the landscape patterns. Based on fractal geometry (Mandelbrot 1977), a landscape is deemed more complex when the fractal dimension is higher (usually >1, approaching 2). This is important for scaling various basic phenomena such as causal factors of landscape patterns (Turner 1989, Keitt *et al* 1997). The fractal dimension of a patch can be computed by the area-perimeter relationship as shown by Mandelbrot (1977). FRAGSTATS uses this method to compute the ***patch fractal dimension*** for patches and its simple extension to class and landscape levels, the ***mean patch fractal dimension***. An ***area-weighted mean patch fractal dimension*** is computed to avoid patch-size biases. When the number of patches are small (e.g., <20), McGarigal and Marks (1995) recommend computing fractal dimension based on patch fractal dimension. The landscape/class fractal dimension can also be computed also by regressing the log perimeter on log area (Burrough 1986), a method McGarigal and Marks recommend when a sufficiently higher number of patches exists.

3.1.3 Isolation Indices

Another indication of fragmentation at the patch, class, or landscape level is the relative isolation of landscape components. Isolation indices fall into 2 categories:

- At the simplest level (edge-to-edge separation), the isolation of a patch is assessed by its ***nearest-neighbour distance***. This simple index can be extended to landscape/class levels by computing the ***mean nearest-neighbour distance*** (sum of all patch nearest-neighbour distance values divided by the number of patches). Similarly, the ***nearest-neighbour standard deviation*** and the ***nearest-neighbour coefficient of variation*** are computed to assist statistically valid inferences at landscape/class levels. Higher values of nearest-neighbour indices imply greater isolation.
- The ***proximity index*** (Gustafson and Parker 1994) computes isolation values at the patch level by using a user-specified search radius from the focal patch; the ***mean proximity index*** averages values at landscape/class level. The key value of the proximity index is that it assesses the spatial configuration of a complex of patches surrounding the focal patch (Gustafson and Parker 1994). It is based on the distance to neighbours and the patch areas of those neighbours, within a search radius. This index improves on the nearest-neighbour distance index by area-weighting larger neighbours within the specified radius. Larger proximity index values indicate less isolation.
- LEAP II computes the ***interspersion index*** to indicate the intermixing of patches. This highly intuitive index was proposed by McGarigal and Marks (1995). At both the class and landscape levels, this index is based on the probabilities of a patch of a given class being adjacent to patches of the other classes. A low interspersion index implies less intermixing of patches. An interspersion index that approaches 100% indicates the greatest possible patch intermixing.

As with all other indices, the strength of the inferences from these isolation indices are valid only if they are referenced to benchmark values in either space (cause and effect) or time (long-term trends).

3.1.4 Edge Indices

The ***edge*** concept is one of the most studied in landscape ecology (e.g., Hansen and di Castri 1992, Forman 1995); without edge, there are no patches, landscape mosaics, spatial patterns, or an inter-patch flow (organisms or material) differential. Edge indices fall into 2 categories:

- The simplest index is the ***edge*** of a given patch: the linear perimeter as determined by the patch definition. ***Total edge*** extends this parameter to class and landscape levels, and ***edge density*** standardizes comparisons among different spatial extents. Those indices measure the simple structural edge of a landscape.
- LEAP II also uses a group of FRAGSTATS indices to examine the *functional edge* of a landscape. Depending on the objective (e.g., ungulate movement, bird predation, or fire spread), an edge between 2 patches may or may not be functionally significant. The interface between some classes can be high contrast (e.g., land and water; dense forest and agricultural land) or low contrast transitions (e.g., 2 dense forest types, a wetland and a lake). The ***edge contrast index*** estimates the relative proportion of "real" edge to simple perimeter edge, relying on pair-wise class interface weighting determined by the user. If perimeter interface segments of a patch are all drastic, the edge contrast index will be 100%. Conversely, if most perimeter segments are low contrast transitions, the patch

will have a lower (<100%) edge contrast index. This index is extended to landscape/class levels via the ***total edge contrast index*** and ***mean edge contrast index***. To emphasize the significance of large patches, LEAP II provides an ***area-weighted mean edge contrast index***. Edge density can be computed in a contrast-weighted manner, producing the ***contrast-weighted edge density*** for classes and the landscape. Relatively higher contrast-weighted edge indices imply a sense of higher functional isolation and fragmentation.

3.1.5 Interior Indices

The *interior* or *core area* of a patch is determined by its non-interior or edge. Therefore, interior index assessments require the user to define the *non-interior*, by assigning a *buffer width* to the patch perimeter. This buffer width represents the edge effect's extent into the patch and presents the interface in 2-dimensional edge area. In contrast to the landscape structural indices discussed thus far, interior indices depend entirely on the user's objective-based input *a priori*. These indices fall into 2 categories:

- ***Core area*** is the total patch area minus the edge area. Extending this index to landscape/class levels results in the ***total core area index***. The relative proportion of the patch that is core is indicated by the ***core area percentage***, which approaches 100% when the edge is minimal and 0% when edge area predominates. Similarly, ***total core area index*** indicates the relative core area in the landscape and each class. The ***mean core area index*** represents average patch condition at each level (the core area divided by the number of patches). At the class level ***core area dominance index*** provides the relative proportion of the landscape occupied by the interior area of that class.
- A second set of interior indices quantifies the number of core areas in a landscape. Each patch can be examined for the ***number of core areas***. Based on the number of core areas of each patch, the following can be computed for each class and the landscape: ***number of core area***, ***core area density*** (per 100 ha), ***mean core area per patch***, ***patch core area standard deviation***, and ***patch core area coefficient of variation***. For all the above means, the patch number is used as the denominator. However, depending on its shape and the given buffer width, a patch may contain more than 1 core area. McGarigal and Marks (1995) termed these *disjunct core areas* of a patch. Some of the above indices can also be calculated using the number of disjunct core areas as the denominator; at the class and landscape levels, these indices include ***mean area per disjunct core area***, ***disjunct core area standard deviation***, and ***disjunct core area coefficient of variation***.

3.2 Landscape Compositional Indices

These indices are abstract, apply only to the landscape level, and are very sensitive to the definition of classes. As a group, these indices (extrapolated from community ecology) examine the concept of *diversity* of component classes within landscapes. These diversity indices are non-spatial and do not reflect the spatial geometry of the class distribution. In addition, they do not measure *species diversity* at the landscape level.

3.2.1 Richness Indices

Class richness indicates the number of distinct classes in a given landscape, providing a simple index of diversity. To allow comparisons of landscapes with different extents, LEAP II computes ***class richness density*** (#/100 ha).

3.2.2 Evenness Indices

An *uneven* landscape has a few classes with large areas and many classes with small areas; conversely, the classes of an *even* landscape are all equal in area. Thus *evenness*, also known as *equitability* (Peet 1974), indicates class dominance within a landscape. Evenness measures range from 0 (very high dominance) to 1 (no dominance). LEAP II computes evenness using the ***Shannon evenness index*** (Shannon and Weaver 1949), the ***Simpson evenness index*** (Simpson 1949), and the ***modified Simpson evenness index*** (Pielou

1975). The choice of index depends on the familiarity of the user, since these indices are similar in validity and ecological phenomena.

3.2.3 Heterogeneity Indices

LEAP II's working definition of *heterogeneity* follows Peet (1974) rather than Li and Reynolds (1995). Heterogeneity indices quantify both richness and evenness components of diversity, are used extensively in community ecology (e.g., Krebs 1989), and were proposed for use in landscape ecology by O'Neill *et al* (1988). The 2 types of heterogeneity indices (after Peet 1974) are:

- Those that are sensitive to changes in the rare classes in a landscape, including the ***Shannon diversity index*** (Shannon and Weaver 1949).
- Those that are sensitive to the changes in dominant classes in a landscape, including the ***Simpson diversity index*** (Simpson 1949) and the ***modified Simpson index*** (Pielou 1975).

Interpreting heterogeneity indices must not be done simply or in isolation of other measurements. High heterogeneity indicates a landscape has many classes and/or its area is distributed evenly among its classes. To have meaning, heterogeneity values must be explicitly related to an ecological goal or an objective. For example, a landscape's heterogeneity may be compared with its intrinsic (predicted) potential for heterogeneity.

3.3 Landscape Connectivity Measurement

Internal movement of organisms and material is a fundamental landscape process that is a function of the landscape composition and spatial pattern. The landscape characteristic that enables such movement is *connectivity* (Merriam 1984), which indicates the relative suitability of land cover for movement of organisms or material. Movement can be *directional*, e.g., animals migrating toward shelter or food, or *non-directional* e.g., fire spread. Connective paths for directional movements are called *corridors* (Saunders and Hobbs 1991, Cook and Van Lier 1994, Rosenberg *et al* 1997). LEAP II's ***landscape connectivity measurement*** allows the user to quantify the area of connectivity and length of corridors.

3.3.1 Spread Analysis

LEAP II allows the user to analyze species or material spread based on land cover suitability and distance. The user can convert each pixel in the landscape is converted from a landcover class value to a *friction* value, based on species ecology (e.g., moose habitat suitability) or process dynamics (e.g., forest fire fuel). These values are nominal integers and can be linear or non-linear, based on the user's judgement (e.g., no friction = 1, low friction = 2, medium friction =5, very high friction=100). Spread is tracked on a pixel-to-pixel basis. The inter-pixel distance is scaled to 1 for non-diagonal movement or to v2 for diagonal movement. Given a start point, a relative numerical *cost* value is derived for each landscape pixel, as a function of the friction values and distance to start point:

$\mathrm{Cost}_y = \mathrm{Cost}_x + 0.5[F_x + F_y] \,.\, D_{xy}$
Where,
Cost_y = Cost at pixel Y,
Cost_x = Cost at pixel X,
F_x = Friction value of pixel X,
F_y = Friction value of pixel Y, and
D_{xy} = Distance from pixel X to Pixel Y (v2, if diagonal, 1 if non-diagonal).

Note that the formula computes the *cumulative* cost, from a point of reference decided by the user. For example, if all friction values are null (1), then the cumulative cost is equal to the distance. Computed cost values are displayed as a contour map, within the limits of *threshold cost values* set by the user. For an example of the use of spread analysis, see Chapter 8.

3.3.2 Corridor Analysis

LEAP II's ***corridor analysis*** function detects the existence of least-cost pathways in between using 2 points of reference (e.g., 2 woodlot centroids among other land cover types). Spread analysis is conducted for each reference point, and the 2 cost surfaces are merged. Thus, each landscape pixel has the sum of cost to reference point 1 and to reference point 2. LEAP II also produces a cost surface map, bounded by a user-defined threshold value (maximum possible value for a corridor). This corridor surface will have contours that define regions of equal cost for movement.

3.3.3 Linkage Analysis

When more than single reference points are used to derive corridors, LEAP II can develop a linkage surface. Pair-wise corridors are overlaid, and the resulting surface encompasses all corridors (bound by the threshold values). Each pixel of that surface assumes a value equal to the number of corridors it overlaps.

CHAPTER 4

Using LEAP II Effectively

This chapter explores important issues to consider before and while using LEAP II. Also see the case studies in Chapters 5-8.

4.1 Setting Goals and Objectives

For other than exploratory work, LEAP II requires an explicit goal. It is tempting to "run it all" and sort the results of the process later. In the long run, however, this approach can be very time consuming. For each analysis, the user must address critical issues of resolution, classification, and parameters that determine how the results can be used. In general, up to 90% of the time allotted to a typical analysis should be devoted to *preparing* to use LEAP II.

4.2 When Is LEAP II the Right Choice?

To answer this question, the user must determine if the analysis requires LEAP II and spatial or tabular data or if other tools will meet the objectives. Then the user must ask whether the questions relate to available data. In some cases, questions cannot be easily represented with available data. For example, if the habitat use of a species is related to soil moisture, then analyzing landscape structure using land cover data is not useful.

Even if the user has appropriate data, the resolution required may not be practical. For example, if the question involves identifying narrow strips of vegetation along hydrologic features, fine resolution data is necessary. Completing this analysis over a very large area involves very large datasets and extensive hardware, thus tools that use vector-based approaches would be more appropriate.

4.3 Database Preparation and Classification

4.3.1 Knowing the Data

To apply LEAP II successfully, the user must have appropriate and good quality data and must *understand* this data. Many datasets are constructed in pieces; in most cases, they have not been joined for use over large spatial extents (for example, a polygon that straddles 2 adjacent map sheets). Ideally, a polygon fragment is given the same entity and attributes in each map. To reconstruct the larger entity, it must *at least* have the same attributes. If the attributes are not identical (or if the boundaries do not align), spatial analysis will be invalid.

The format of attributes is also important. In many cases, attributes need to be changed or amalgamated before the data is sent to LEAP II. For example, if the desired analysis involves fixed age classes, the user can save time by creating a new attribute with these age classes rather than constructing them separately as part of more complex class definitions. Attributes are made up of several pieces in a string, e.g., *Sw 6 Pw 2 Pr 2*, a typical species composition string separated by species and the corresponding proportion.

4.3.2 What Is the Landscape?

Defining the analysis boundaries is critical to using LEAP II successfully. Ideally, the landscape should be defined in units that are relevant to an ecological phenomenon, e.g., a species' habitat range. However, for an ecological process that operates at broader scales, the relevant unit may be an ecological land class, e.g., an eco-district. Using an ecologically based analysis unit may not be possible when planning for an administrative or ownership-based area such as a township or management unit. In some cases, data from the surrounding area can be used to smooth out the effects of these administrative boundaries.

4.4 Building Base Data, Selecting Indices, and Setting Parameters

After defining the analysis boundaries, the user must construct or prepare the base data to create classified landscapes. This task involves:

- Understanding the classification(s) the base dataset must support.
- Ensuring the availability of the attributes necessary to build appropriate classifications.
- Ensuring that only required information is included.
- Sketching out the classification needs while considering the attributes and limitations of the base data.
- Making up the base dataset.

4.4.1 Developing Classifications

Developing an effective classification is a balancing act. The user must include enough detail to represent the basic units that drive the phenomenon being analyzed but at the same time eliminate unnecessary detail. For example, if the question relates to a specific tree species, but other species in the area act similarly with respect to this question, then the classification need not be based on all species in the area.

It is tempting to work from a "run it all" approach, but more detail is not always better, and in many cases, it confounds trends that might be important. The more focussed the classification is, the easier it will be to interpret. Over-generalization can also cause problems. For example, if a certain conifer species will be harvested heavily over the next few decades, lumping all conifers into 1 class could prevent the identification of this trend.

The defined classes must also be appropriate for all of the landscapes to be analyzed, whether the comparison is between a baseline landscape and several scenarios (or among the scenarios) or among several landscapes in a time series. Most indices cannot be used to compare differently classified landscapes or different input parameters, such as resolution and edge buffer width. Again, time invested prior to analysis will save time later, and more importantly, help ensure that appropriate trends are revealed.

4.4.2 Determining Resolution

Unfortunately, no rigorous rules exist for determining the appropriate resolution for a LEAP II analysis. Exploring the data and knowing the context of the phenomena being studied are critical. The user should begin by asking an obvious but often overlooked question: *Do the basic units depict what we want examine?* For example, if the problem is based on stand-level processes, then the resolution should be able to discern the majority of the stand units. On the other hand, for coarse-level questions, such as forest vs. non-forest based phenomena, a fine resolution that can define each stand unit is not necessary. A general rule-of-thumb is to use coarse data when analyzing large spatial extents, thus easing hardware demands and simplifying interpretation of the results.

4.4.3 Selecting LEAP II Indices

Indices used should be limited to those that:

- Illustrate trends appropriate to the question and the classification.
- Illustrate the objectives.
- Quantify whether the objectives were reached.

The user must know the indices' strengths and limitations. The most common limitations relate to the number of classes; with very few classes, some measures are irrelevant, and with too many, other measures lose meaning.

To select indices:

- Determine which indices relate to the objectives.
- Eliminate indices that do not relate to the objectives. For example, why run isolation measures if the phenomenon of interest is related strictly to patch boundary shape?
- Determine the amount of detail required and identify the indices that could provide important background or supporting measures. For example, to compare patch size distributions over several landscapes, the user needs the standard deviations of these patch sizes.

4.4.4 Setting Parameters – Edge Buffer Distance

Each LEAP II analysis requires specific parameters related to certain indices. For example, to examine interior forest, the user must first define *interior* by establishing a buffer width. This parameter must remain constant between runs if the results will be compared. Buffer width must be a multiple of the data resolution. The resolution must be finer than the desired edge buffer distance, because pixels cannot be subdivided to calculate edge/interior.

4.4.5 Setting Parameters – Proportion of Boundary as Edge

The objectives must reflect landscape boundaries. In many cases, the boundaries are defined by arbitrary, political, and administrative criteria. The effect of this usually uniform, straight boundary can be adjusted using the ***proportion of boundary as edge*** parameter. If the phenomenon examined does not relate to this boundary, weight these outer edges lower than the internal landscape edges or exclude them from computations. For example, moose habitat is not likely to be affected by a township boundary. In some cases, this outer limit *is* a true edge, for example, in a protected area surrounded by farms or development.

4.4.6 Setting Parameters – Edge Contrast Weights

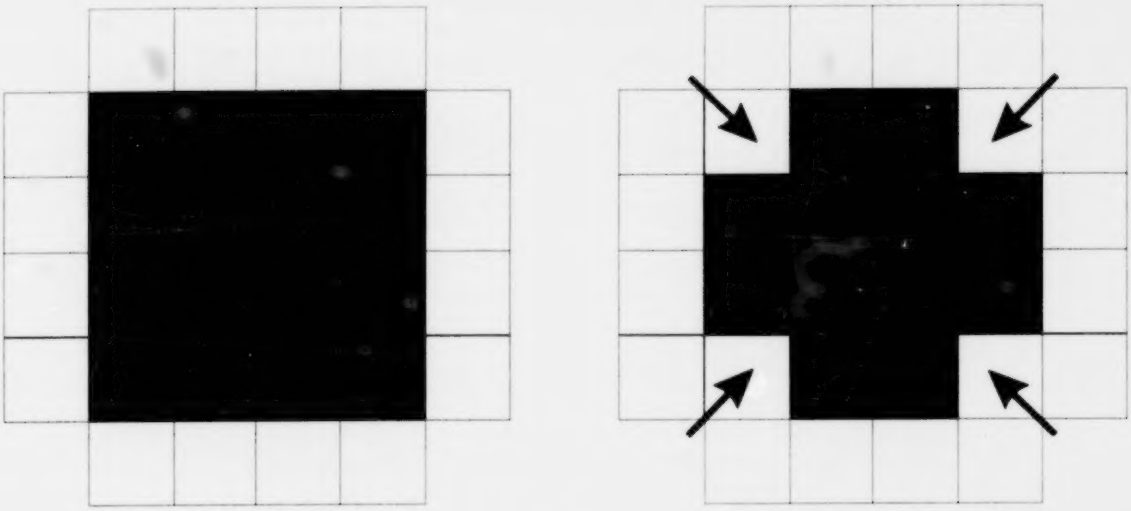
LEAP II provides a useful feature for examining edge relationships: weighting pair-wise interfaces with respect to an objective. This feature allows the user to examine very specific interrelationships on the landscape and cases where the phenomenon is affected differently by different edge interfaces. For example, a wildlife species may not be affected by moving between 2 conifer forest cover types, but it might be adverse to a conifer forest/developed area interface. These varying interfaces can be weighted accordingly to calculate the landscape edge in relation to the phenomenon being studied.

4.4.7 Setting Parameters – Proximity Distance Limit

This parameter is essential to compute the mean proximity index. It defines the search radius used around each patch of a given class, to examine their neighbour area.

4.4.8 Setting Parameters – Diagonal Neighbours

The parameter ***diagonal neighbours*** determines how interior (core) areas are defined. *Interior* is identified as the area of the patch remaining after a buffer width is specified. The ***diagonal neighbours*** parameter directly affects how this buffer is imposed: either straight side to side, up and down, or with diagonal directions. Figure 1 illustrates the differences between these methods.


No diagonal used (overestimates interior area)

Diagonals used (underestimates interior area)

Figure 1. The effect of diagonal searching for forest interior.

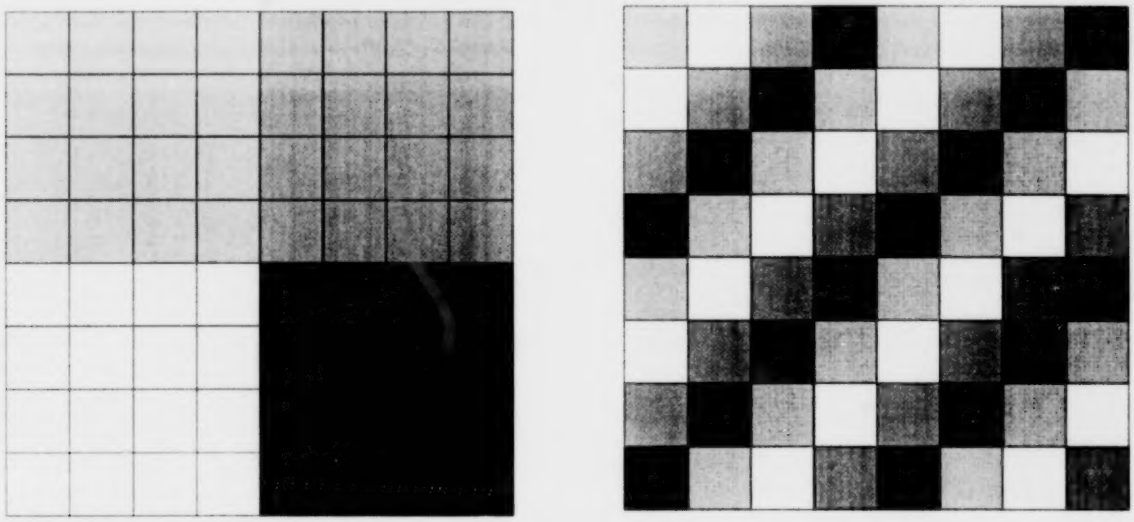
4.5 Interpreting LEAP II Analyses

During the interpretation process, the user must keep the goals and objectives in mind. However, *absolute* objectives and targets for individual indices are rare, partly because baseline values may not be available. Particularly with analyses of different geographic areas, the values obtained may be the first ones, with no previous reference points. These values are useful for future monitoring.

In most cases, to determine progress toward objectives, the user must carefully analyze the *directional trends* of various indices. All interpretation must be made in the context of the analysis objectives, since an index moving in a direction deemed favourable for 1 objective or 1 area might be detrimental for another objective or area.

Interpretation should also be made within the context of the parameters selected. For example, conclusions about the measures of interior area in a landscape are relevant only given the selected edge buffer. With a different buffer width, these values and subsequent interpretations could be quite different. Comparisons between scenarios or time series can be made only if the parameters and classifications remain constant. Comparisons between landscapes for different extents should also be made very carefully, if at all. Indices that standardize the results by the landscape extent are useful for these comparisons. For example, comparing absolute values of total edge between 2 areas is not appropriate, but edge density can be compared as a measure of landscape complexity, as long as the parameters and classifications remain constant.

Eliminating indices not relevant to the objective will simplify interpretation. In some cases, however, the user may need to examine seemingly less relevant indices to allow more detailed conclusions about observed patterns. For example, Figure 2 illustrates 2 very different landscapes that have an equal amount of all of the defined landscape types. The diversity measures for these landscapes are identical because they are based on the number of types (richness) and the proportion within the types (evenness). To illustrate the true nature of these landscapes, other indices, such as interspersion, contagion, or mean patch size, must be examined.



Landscape A

Landscape B

Figure 2. Diversity values for Landscape A and B are identical, yet these landscapes are quite different in structure.

4.6 Using the Spread Analysis

Many of the principles outlined in Sections 4.1-4.5 also apply to LEAP II spread analyses. The following information, however, is specific to using the spread analysis module.

4.6.1 Can Spread Analysis Be Used Effectively?

LEAP II's spread analysis function is designed to examine phenomena that involve spatial movement through the landscape. The first step in using this function is to determine whether reasonable units of this movement can be measured using the available data. To quantify the spread, the landscape must be classified into units that are assigned relevant impedance values. In addition, the phenomenon must spread from single source points (i.e., fire ignition points, den locations).

4.6.2 Preparing the Database

The first step is to determine what the dataset can and cannot depict. For LEAP II to work, the data must be able to depict the flow pattern and range. For example, if a species' normal home range is 100 km^2, analyzing smaller areas is pointless. Data resolution is also critical; it must reflect a reasonable unit of movement for the phenomenon. For example, if a species typically travels 20 km per day to find food, a resolution of 10 km x 10 km would not adequately represent this movement.

4.6.3 Classifying the Landscape

Classifying the landscape for spread analysis should focus on eliminating information not directly related to the question at hand. For each defined class, the user must understand how the phenomenon spreads through this class relative to all of the other classes. Classes that act the same do not need to be differentiated. For example, if a species travels through 2 types of pine forest cover in exactly the same way, then the classification need not differentiate between those cover classes. Generally, a *useful* classification is one that can be explained and interpreted easily.

4.6.4 Assigning Friction Values

The relative friction values assigned to landscape classes should correspond to a unit of movement or energy related to the phenomenon. For example, when analyzing how a species moves from its home to find food, *kJ of energy expended* would represent reasonable units to assign to the landscape classes. Another example: To analyze fire spread, *relative fuel values* should be assigned to landscape classes.

4.6.5 Selecting a Threshold Value

Threshold values should relate to the objectives and the units assigned to the classes. For an analysis of the movement of a species from its home to find food, an appropriate threshold might be the total amount of energy that the animal would expend in 1 day to find food. A higher threshold could be used to map the relative spread of a phenomenon over a larger portion of the landscape.

The threshold value can also be used iteratively to evaluate levels of spread or connectivity. For example, a low threshold could be used until a connection appears between 2 points or the level needed to spread to a specific point on the landscape. Thus the user can determine the level of energy needed to join the points or can map networks of connections at different cost levels.

4.7 LEAP II Case Studies and User Instructions

The rest of this guide presents case studies that illustrate how LEAP II can be applied (Chapters 5-8) as well as instructions for starting and using LEAP II (Chapters 9-12). Appendices I and II provide information on installing LEAP II and formatting data files.

The first 3 case studies illustrate the use of LEAP II's ***landscape pattern indices*** and the fourth demonstrates ***landscape spread analysis***. The case studies, including all of the datasets and results (tables, graphs, images), are provided to serve as a tutorial to help the user become familiar with LEAP II. Unfortunately, many of the images presented are not particularly clear in black and white. To examine them in colour, use the case study material provided on the CD-ROM.

Figure 3 depicts the general process for analyses performed using both of LEAP II's major components. The step numbers on each side of the figure are used as references in the case studies. A typical analysis process can have an infinite number of iterative loops.

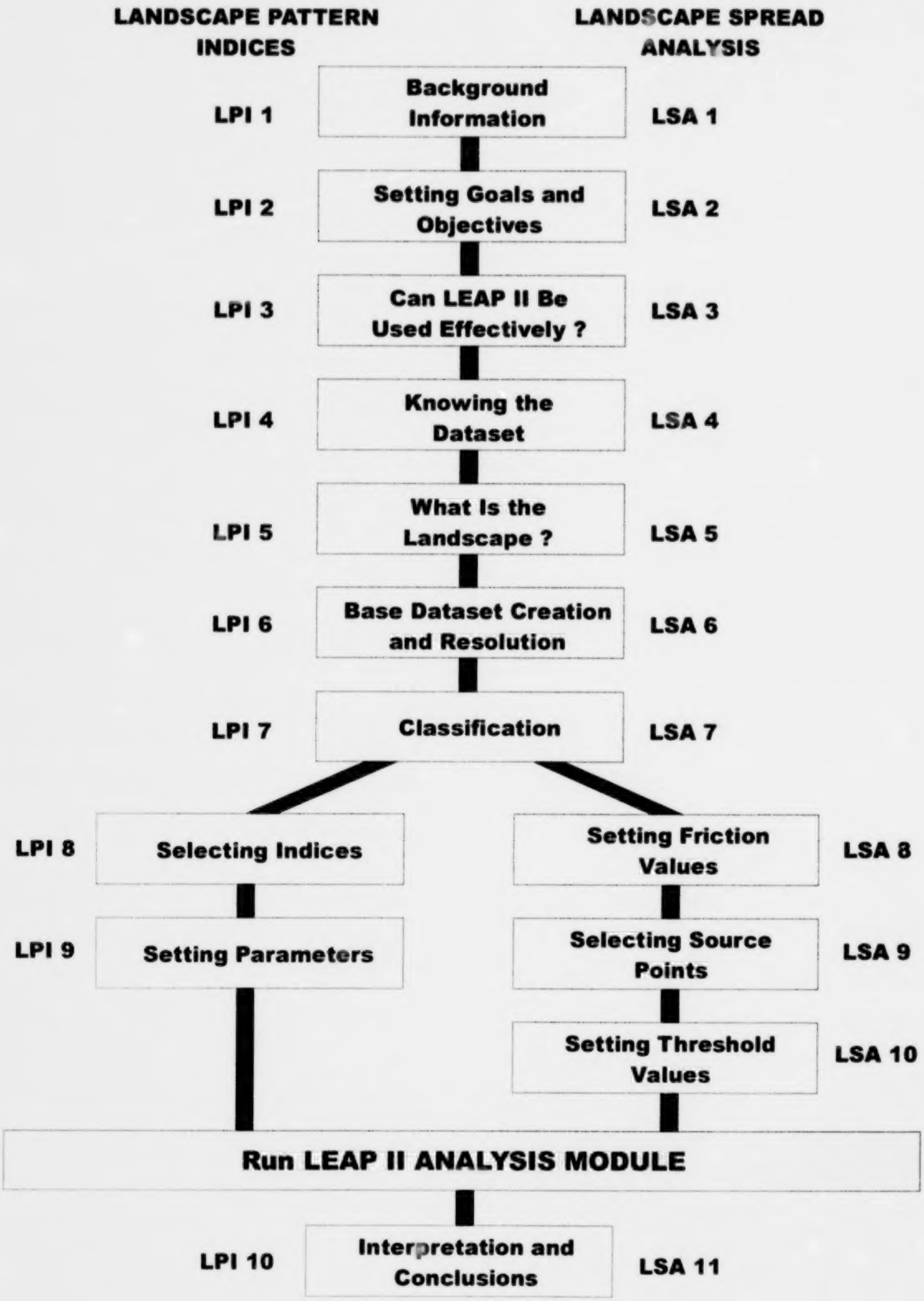

LANDSCAPE PATTERN INDICES
LANDSCAPE SPREAD ANALYSIS
LPI 1
Background Information
LSA 1
LPI 2
Setting Goals and Objectives
LSA 2
LPI 3
Can LEAP II Be Used Effectively ?
LSA 3
LPI 4
Knowing the Dataset
LSA 4
LPI 5
What Is the Landscape ?
LSA 5
LPI 6
Base Dataset Creation and Resolution
LSA 6
LPI 7
Classification
LSA 7
LPI 8
Selecting Indices
Setting Friction Values
LSA 8
LPI 9
Setting Parameters
Selecting Source Points
LSA 9
Setting Threshold Values
LSA 10
Run LEAP II ANALYSIS MODULE
LPI 10
Interpretation and Conclusions
LSA 11

Figure 3. Process for LEAP II case study analyses.

CHAPTER 5

Case Study 1: Exploring a Landscape

Case Study 1 illustrates the use of LEAP II for data exploration and baseline analysis. As planners with a fictional forest company using both conifer and hardwood for pulp, we wanted to explore the landscape from different perspectives and generate a baseline set of indices that describe the current state of the forest for the management unit.

5.1 Setting Goals and Objectives (LPI 2)

Although much of this analysis was exploratory, it still required goals and objectives:

Goal 1: Visualize the entire management unit in terms of relevant classifications and summarize its basic characteristics. **Objectives:**

- Prepare base data for the entire unit to visualize useful themes.
- Develop classified landscapes relevant to the operations and concerns of the planning process.

Goal 2: Examine how changes in resolution affect the depiction of the landscape and edge. **Objectives:**

- Prepare and examine base datasets at different resolutions to determine the effect of changes in resolution.
- Generate edge statistics for each resolution to determine changes in edge measurement.

Goal 3: Generate a baseline set of indices for comparison with future activities. **Objectives:**

- Develop a classification scheme relevant to harvest operations and wildlife habitat concerns.
- Generate a set of landscape-level measures to quantify the landscape structure.

5.2 Can LEAP II Be Used Effectively? (LPI 3)

We concluded that LEAP II was an appropriate choice to meet our goals, because it could:

- Help us become familiar with a landscape and summarize simple measures like area per class, which other tools can do as well. However, unlike many other tools, LEAP II could also allow us to examine the data for the entire unit quickly and simultaneously and to reclassify the unit from a simplified dataset.
- Handle spatial data using a raster-based approach.
- Provide a simple means of classifying the landscape and measuring a variety of spatial indices.

5.3 Knowing the Dataset (LPI 4)

The first step in exploring the management unit at the landscape level was to become familiar with the technical details of the data. The dataset includes detailed species, site and ownership information used in the timber supply and other management planning functions. Most of the required landscape-level planning was based on attributes of dominant cover type and age. To ease classification and interpretation, age was categorized into 20-year classes. The township-based tiles of data are well edge-matched in the dataset.

5.4 What Is the Landscape? (LPI 5)

In this analysis, the landscape was limited to the administrative bounds of the management unit because surrounding data was not available.

5.5 Base Dataset Creation and Resolution (LPI 6)

The first step was to use the LEAP Builder to generate a base dataset that included 2 attributes: cover type and age class (Table 4).

Table 4. Attributes included in the base dataset include dominant cover types and age classes.

Dominant Cover Types						Age Classes	
Conifer 1	Conifer 4	Decid 1	Open 1	Wetland 1	Developed	1 (0 - 20)	4 (60 - 80)
Conifer 2	Conifer 5	Decid 2	Open 2	Wetland 2	Water	2 (20 - 40)	5 (80 - 100)
Conifer 3	Conifer 6	Decid 3	Open 3	Wetland 3		3 (40 - 60)	6 (> 100)

For Goal 1, we selected a resolution of 50 m to depict the landscape. Examining the multiple-resolution datasets for Goal 2 would help determine if this resolution is appropriate. For Goal 2, we used the LEAP Builder to create 4 base datasets with the same attributes listed in Table 4 but at 25, 50, 100, and 200 m resolutions.

5.6 Classification (LPI 7)

Goal 1 focusses on generating classifications that will help to depict the landscape in meaningful ways with respect to forest harvest activities and habitat supply for appropriate species. Most of these issues are related to dominant cover type and age. We included all of the classes in each scheme because the goal and objectives do not specify that some are more important than others. Figures 4-6 show the classifications we developed based on these attributes.

For Goal 2, we used the cover type classification to compare the effects of changing the resolution. To create the landscapes, we classified each of the base datasets at varying resolutions, using the same classification (Figures 7-10).

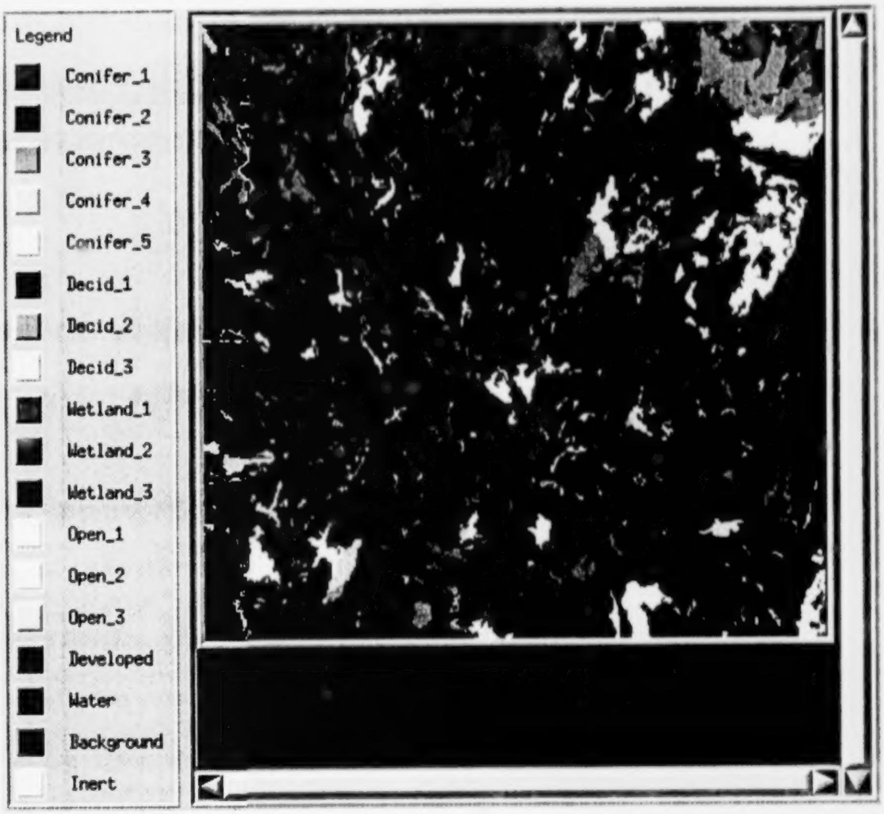

Legend
Conifer_1
Conifer_2
Conifer_3
Conifer_4
Conifer_5
Decid_1
Decid_2
Decid_3
Wetland_1
Wetland_2
Wetland_3
Open_1
Open_2
Open_3
Developed
Water
Background
Inert

Figure 4. Cover type classification.

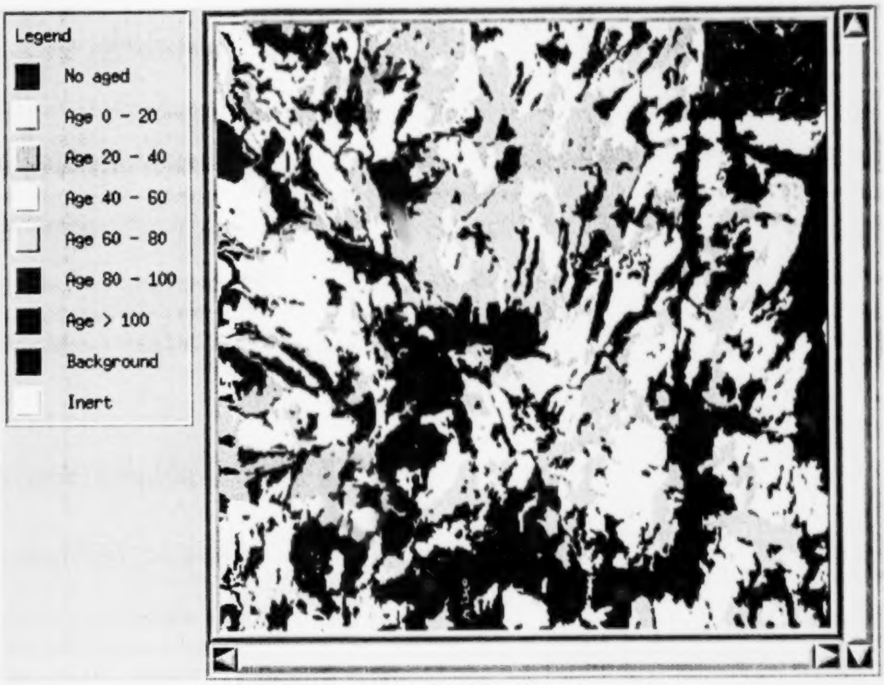

Legend
No aged
Age 0 - 20
Age 20 - 40
Age 40 - 60
Age 60 - 80
Age 80 - 100
Age > 100
Background
Inert

Figure 5. Age class classification.

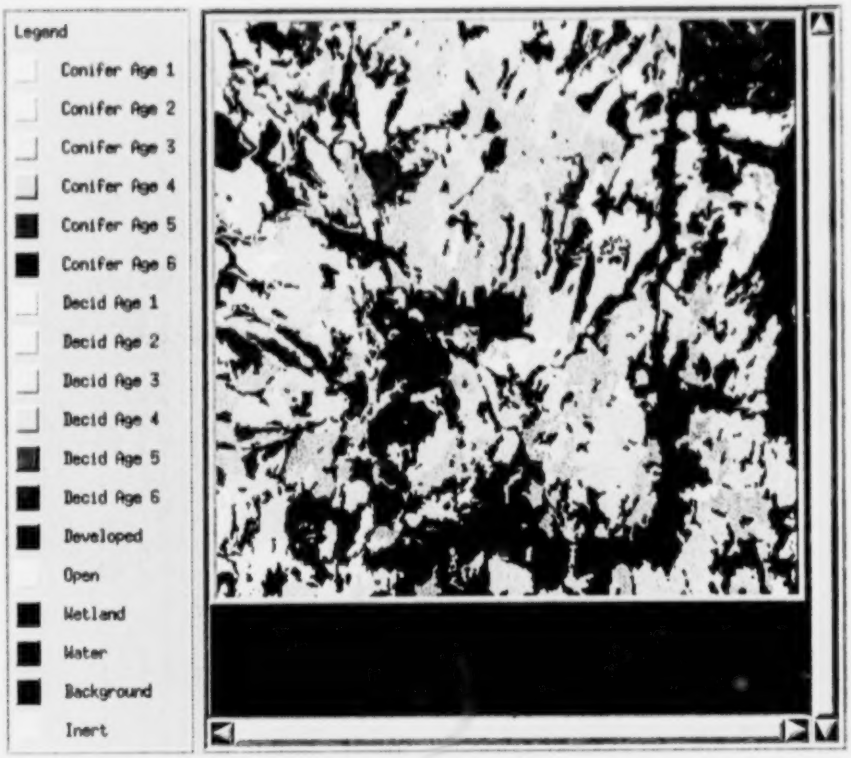

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 6. Broad cover type vs. age class classification.

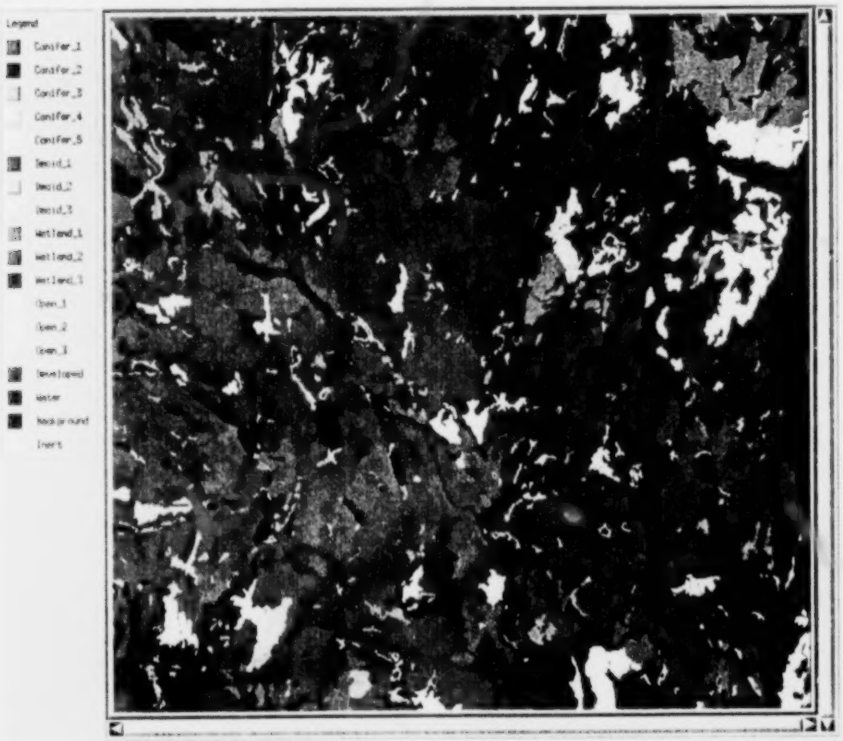

Legend
Conifer_1
Conifer_2
Conifer_3
Conifer_4
Conifer_5
Decid_1
Decid_2
Decid_3
Wetland_1
Wetland_2
Wetland_3
Open_1
Open_2
Open_3
Developed
Water
Background
Inert

Figure 7. Cover types – 25 m resolution.

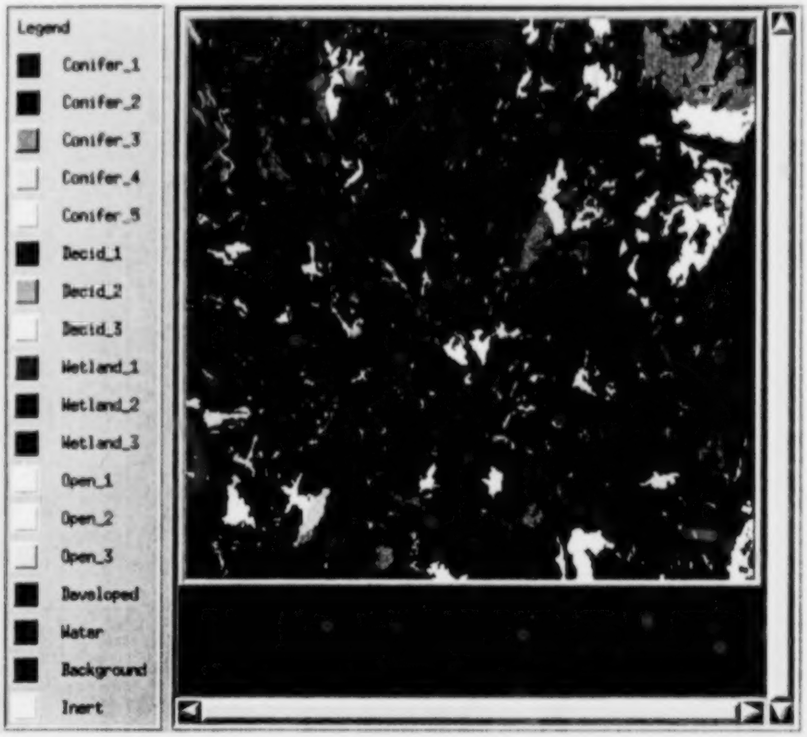

Legend
Conifer_1
Conifer_2
Conifer_3
Conifer_4
Conifer_5
Decid_1
Decid_2
Decid_3
Wetland_1
Wetland_2
Wetland_3
Open_1
Open_2
Open_3
Developed
Water
Background
Inert

Figure 8. Cover types – 50 m resolution.

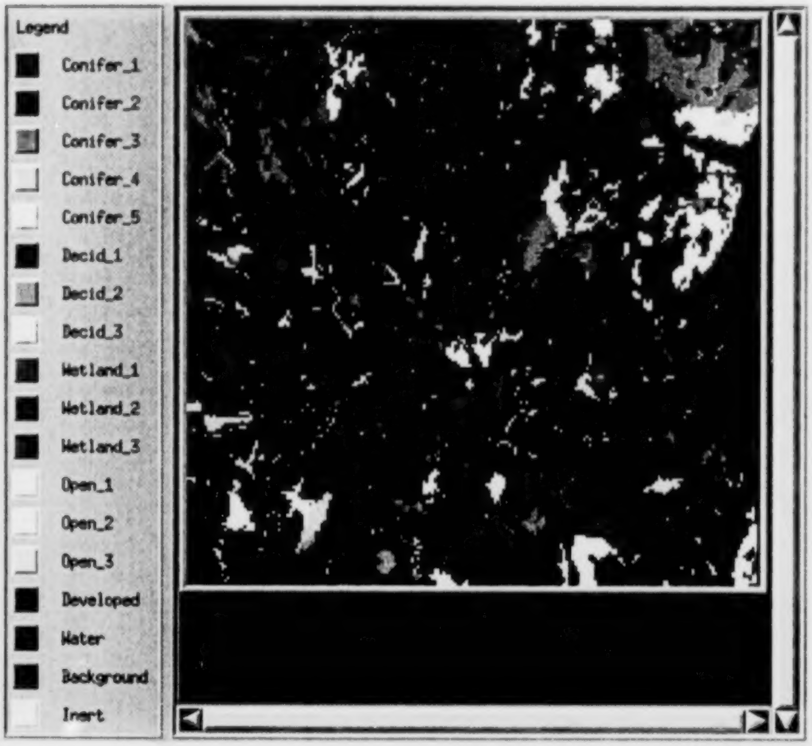

Legend
Conifer_1
Conifer_2
Conifer_3
Conifer_4
Conifer_5
Decid_1
Decid_2
Decid_3
Wetland_1
Wetland_2
Wetland_3
Open_1
Open_2
Open_3
Developed
Water
Background
Inert

Figure 9. Cover types – 100 m resolution.

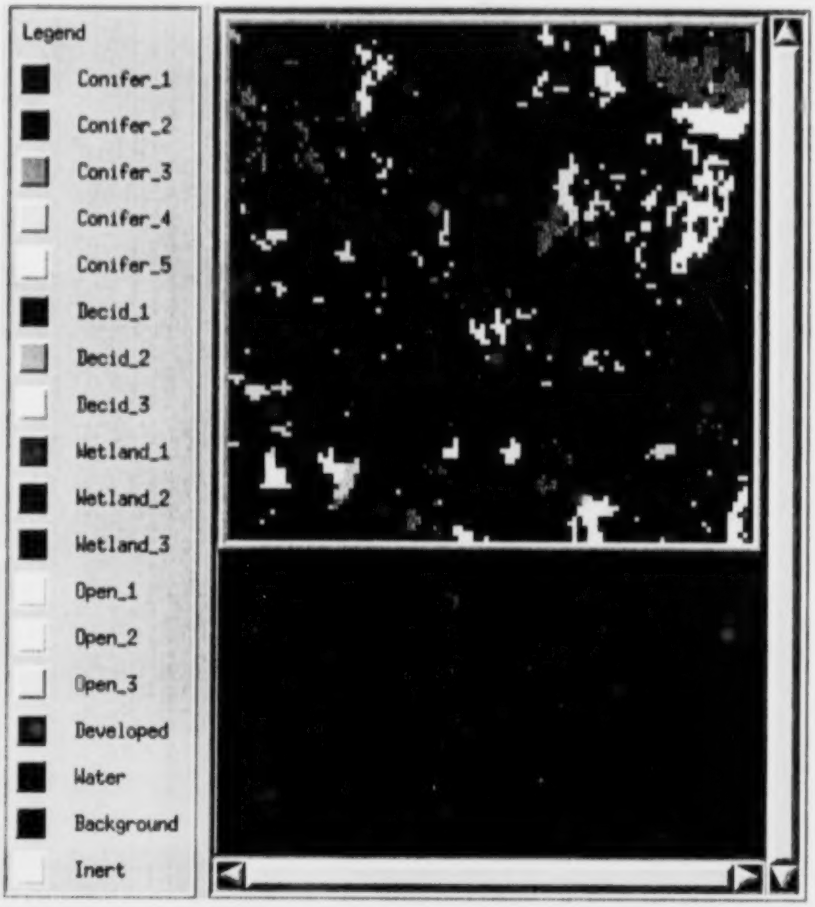

Legend
Conifer_1
Conifer_2
Conifer_3
Conifer_4
Conifer_5
Decid_1
Decid_2
Decid_3
Wetland_1
Wetland_2
Wetland_3
Open_1
Open_2
Open_3
Developed
Water
Background
Inert

Figure 10. Cover types – 200 m resolution.

5.7 Selecting Indices (LPI 8)

To meet Goal 1, we visualized the different landscape classifications and examined the basic composition of each class in the landscape. To reduce processing and interpretation time when running the basic area summaries, we turned off all indices within each level (landscape, class and patch) and used only the main class and patch selections.

For Goal 2, we ran the class area analyses and added the measure of total edge at the landscape level. For Goal 3, we used the preset series of indices calculated for the basic user level.

5.8 Setting Parameters (LPI 9)

The first 2 goals do not involve calculating any core area statistics, therefore, edge buffer distance was not relevant. We also did not use edge contrast weights or a proximity distance. However, the proportion of boundary as edge parameter was important. Because the administrative boundary of the management unit is the limit of the landscape, we set this parameter to 0 to eliminate the artificial edge related to this arbitrary line.

For the analyses related to Goal 3, we selected 100 m for the edge buffer, based on information from a company biologist that this value is relevant to most of the interior species in the management unit. Also on the advice of company biologists, we selected a proximity distance limit of 500 m, which is appropriate for examining the fragmentation of corridors for a number of key species in the management unit. The proportion of boundary as edge was again set to 0 for the reasons mentioned above. Future analyses must use these parameters to ensure comparisons with this baseline are valid.

5.9 Interpretation and Conclusions (LPI 10)

5.9.1 Goal 1

The landscapes presented in Section 5.6 provide visual depictions of the management unit based on cover type and/or age class. Tables 5-7 present the class areas for each of these classifications.

Table 5. Area summary – cover type classification.

Class	Class Area (ha)	% of Landscape	Mean Patch Size (ha)
Conifer_1	8032.50	20.08	77.99
Conifer_2	3407.00	8.52	31.55
Conifer_3	1428.50	3.57	12.31
Conifer_4	195.75	0.49	39.15
Conifer_5	294.50	0.74	36.81
Decid_1	16188.75	40.47	133.79
Decid_2	75.25	0.19	25.08
Decid_3	318.00	0.80	39.75
Wetland_1	1943.00	4.86	41.34
Wetland_2	24.00	0.06	12.00
Wetland_3	355.25	0.89	3.74
Open_1	1032.25	2.58	46.92
Open_2	94.75	0.24	23.69
Open_3	1249.00	3.12	2.92
Developed	270.00	0.68	20.77
Water	5091.50	12.73	14.38

Table 6. Area summary – age class classification.

Class	Class Area (ha)	% of Landscape	Mean Patch Size (ha)
Not aged	7683.75	19.21	20.27
Age 0-20	2281.25	5.70	21.94
Age 20-40	1160.50	2.90	2.97
Age 40-60	12113.50	30.28	103.53
Age 60-80	7754.25	19.39	84.29
Age 80-100	3207.00	8.02	62.88
Age >100	5799.75	14.50	31.18

Table 7. Area summary – broad cover types by age class classification.

Class	Class Area (ha)	% of Landscape	Mean Patch Size (ha)
ConiferAge1	697.75	1.74	41.04
ConiferAge2	45.00	0.11	45.00
ConiferAge3	5687.50	14.22	58.63
ConiferAge4	902.00	2.26	31.10
ConiferAge5	2431.75	6.08	62.35
ConiferAge6	3594.25	8.99	19.53
DecidAge1	260.00	0.65	6.67
DecidAge2	63.00	0.16	15.75
DecidAge3	6426.00	16.07	54.46
DecidAge4	6852.25	17.13	80.61
DecidAge5	775.25	1.94	26.73
DecidAge6	2205.50	5.51	37.38
Developed	270.00	0.68	20.77
Open	2376.00	5.94	5.59
Wetland	2322.25	5.81	18.29
Water	5091.50	12.73	14.38

5.9.2 Goal 2

This second goal calls for examining the effects of changes in resolution on the landscapes and on edge calculations. The landscapes presented in Section 5.6 illustrate the changes in aggregation with the various resolutions. Table 8 summarizes the class areas for the cover type classification at each resolution.

Table 8. Class areas (ha) for landscapes with varying resolutions.

Resolution	25 m	50 m	100 m	200 m
Conifer_1	8014	8033	8086	8216
Conifer_2	3385	3407	3443	3544
Conifer_3	1430	1429	1405	1280
Conifer_4	196	196	194	200
Conifer_5	290	295	290	296
Decid_1	16066	16189	16350	16628
Decid_2	74	75	74	72
Decid_3	317	318	309	328
Wetland_1	1938	1943	1967	1984
Wetland_2	23	24	20	16
Wetland_3	343	355	279	140
Open_1	1032	1032	1040	1096
Open_2	94	95	94	100
Open_3	1259	1249	1100	760
Developed	270	270	261	284
Water	5270	5092	5088	5056
Total	40000	40000	40000	40000

As the resolution changes, some of the classes remain almost constant, while others increase or decrease in both consistent and fluctuating patterns. For example, the water class decreases consistently. This decrease is illustrated in the landscape images; as the resolution becomes coarser, the areas of narrow water features are eliminated because the surrounding classes dominate the larger aggregate pixels.

Table 9 summarizes the effects of resolution changes on edge calculations. As the resolution becomes coarser, edge decreases.

Table 9. Effect of resolution on edge calculations.

Resolution	25 m	50 m	100 m	200 m
Total area (ha)	40000.00	40000.00	40000.00	40000.00
Total edge (m)	2657725.00	2261000.00	1854500.00	1334000.00
Edge density (m /ha)	66.44	56.53	46.36	33.35

5.9.3 Goal 3

The third goal was to generate a basic set of landscape measures to characterize the current state of the forest (Table 10). Many of these indices do not have absolute meaning, but provide a baseline to compare future harvest and succession patterns (see Case Study 3).

Table 10. Indices for broad cover types by age class (basic user level).

Index	Value	Index	Value
Landscape area (ha)	40000.000	Proximity distance (m)	325.368
Number of patches	1620.000	Proximity area (ha)	174.042
Patch density (#/100 ha)	4.050	Heterogeneity (Shannon)	2.332
Mean patch size (ha)	24.691	Heterogeneity (Simpson)	0.885
Total edge (m)	2487650.000	Class richness	16.000
Edge density (m/ha)	62.191	Class richness density (#/100 ha)	0.040
Total core area (ha)	14225.750	Evenness (Shannon)	0.841
Core area density (#/100 ha)	2.785	Evenness (Simpson)	0.944
Total core area index (%)	35.564	Interspersion index (%)	81.403

CHAPTER 6

Case Study 2: Comparing Alternatives

One of LEAP II's most useful applications is analyzing and comparing different landscape scenarios. This case study, a continuation of Case Study 1, illustrates how LEAP II can simulate several management or planning alternatives before they are implemented.

In this case study, our forest company had to prepare a comprehensive management plan for our area of concern. One of the challenges we faced was meeting the legislated habitat requirements of Species X *and* the wood supply quota for the company's mill. Species X requires:

- Large contiguous patches of mature conifer.
- Interior forest greater than 100 m from edges.
- Aquatic feeding areas close to mature conifer.
- Limited human disturbance and open areas.
- Well-connected dense forest cover for travel between feeding sites.
- An extensive range area.

6.1 Setting Goals and Objectives (LPI 2)

In conjunction with the wood supply targets, we developed the following **goal:** Minimize the effects of management activities on Species X habitat. To achieve this goal, we set the following **objectives:**

- Maintain large patches of mature conifer with core areas (100 m buffer).
- Maximize mature conifer/wetland interfaces.
- Minimize mature conifer/harvest areas.
- Ensure connectivity among dense forest patches.

6.2 Can LEAP II Be Used Effectively? (LPI 3)

We determined that LEAP II could be used effectively for questions examined in this case study because it can:

- Conduct spatial analyses to identify core areas at a specified edge width.
- Examine the adjacency and connectivity relationships between various classes on the landscape.
- Analyze the entire unit at once, as long as we specify a reasonable resolution.

Our forest inventory data was appropriate because the habitat requirements of Species X are closely related to landcover structure and composition and do not require explicit definition of fine linear features or detailed stand-level attributes.

6.3 Knowing the Dataset (LPI 4)

For this case study, the dataset was well edge-matched, and we were very familiar with its construction and characteristics. In addition, we already had a composite age class variable (Table 4).

6.4 What Is the Landscape ? (LPI 5)

We knew Species X ranges over large areas at least the size of our area of concern. Since surrounding data was not available, we were constrained to our planning area.

6.5 Base Database Creation and Resolution (LPI 6)

With the goal and objectives in mind, we created two 20-year depletion layouts that could meet both the company's timber demand and the habitat needs of Species X. To meet timber supply goals, we needed to conduct harvest planning using detailed species and stand considerations. This detailed data was not relevant for Species X, as its habitat requirements are based on broad type and age of forest rather than species. We also needed to compare these scenarios to a baseline 20-year projection for an undisturbed forest. For this case study, we simply aged the forest, keeping all forest cover types the same. We applied this same aging to the cut scenarios for all stands, other than those scheduled for depletion.

Using the LEAP Builder, we created LEAP II base datasets for the current condition, the natural projected condition, and the 2 depletion scenarios from our forest inventory database, exporting only attributes for age class and dominant cover type. After some preliminary exploration, we selected a resolution of 50 m to balance the need for edge calculations with the broad classification needs.

6.6 Classification (LPI 7)

After we created the base datasets, we developed a classification to capture the trends relevant to our goal and objectives. We knew that the habitat requirements for Species X are based on mature forest, particularly conifer, and on the relationship of mature conifer to open areas and wetlands. Using the LEAP II classification procedure, we developed the classification outlined in Table 11. We classified the base datasets into the 4 landscapes shown in Figures 11-14.

Table 11. Classification to compare scenarios.

Class	Cover Type	Age Classes
Mature conifer	Conifer 1- 6	4, 5, 6
Mature deciduous	Decid 1 - 3	4, 5, 6
Young deciduous	Decid 1, 2, 3	1, 2, 3
Young forest	Conifer 1 - 6 Decid 1 - 3	1, 2, 3
Wetlands	Wetland 1, 2, 3	N/A
Open	Open 1, 2, 3	All
Developed	Developed 1	N/A
Water	Water	N/A

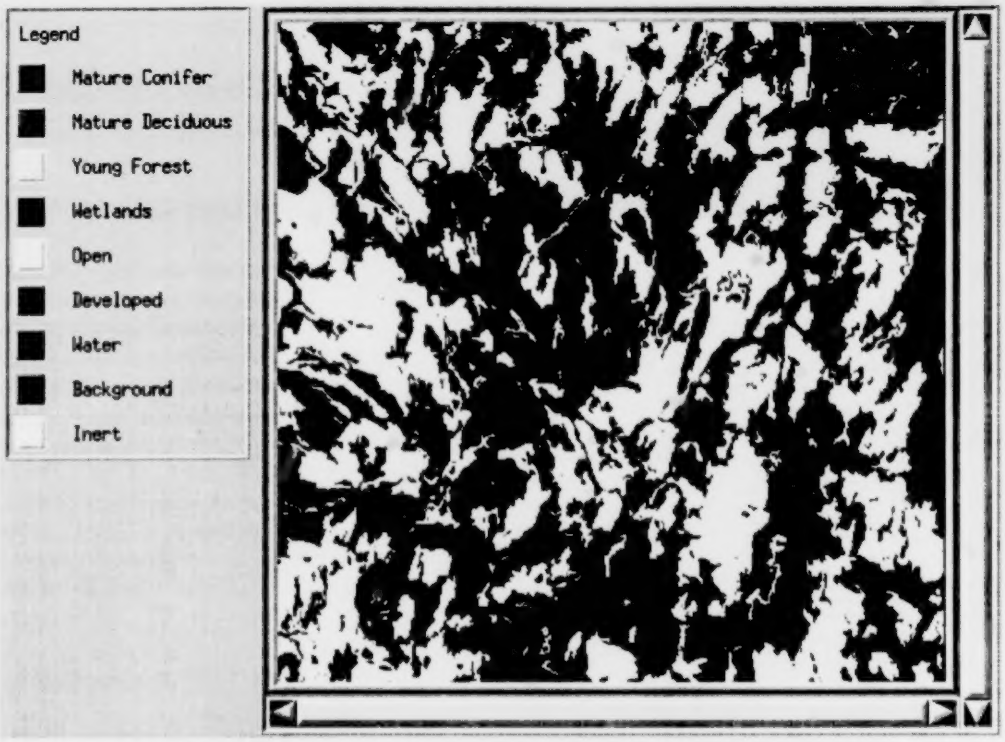

Legend
■ Mature Conifer
■ Mature Deciduous
☐ Young Forest
■ Wetlands
☐ Open
■ Developed
■ Water
■ Background
☐ Inert

Figure 11. Current condition.

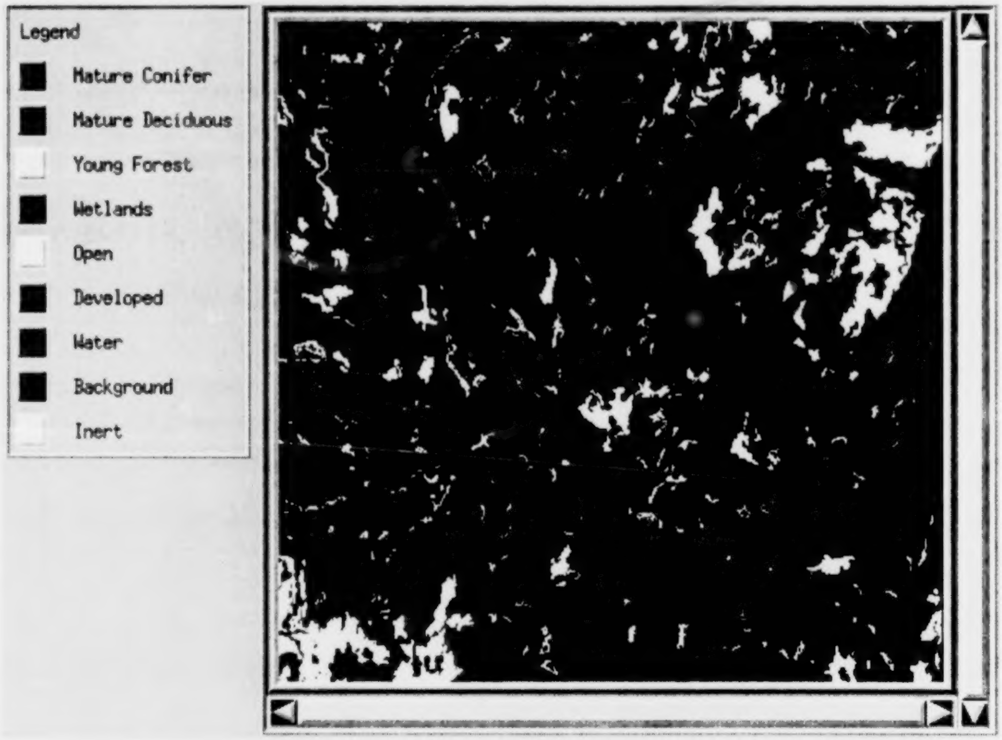

Legend
■ Mature Conifer
■ Mature Deciduous
☐ Young Forest
■ Wetlands
☐ Open
■ Developed
■ Water
■ Background
☐ Inert

Figure 12. Natural forest after 20 years of growth.

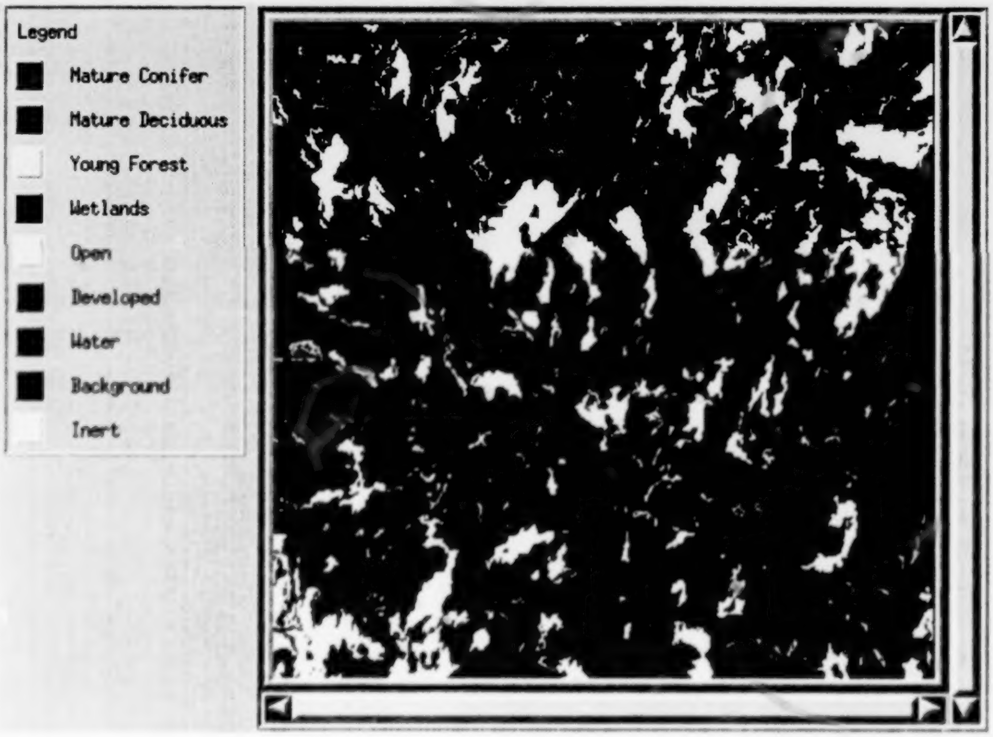

Legend
■ Mature Conifer
■ Mature Deciduous
□ Young Forest
■ Wetlands
□ Open
■ Developed
■ Water
■ Background
□ Inert

Figure 13. Depletion Scenario 1 after 20 years of growth.

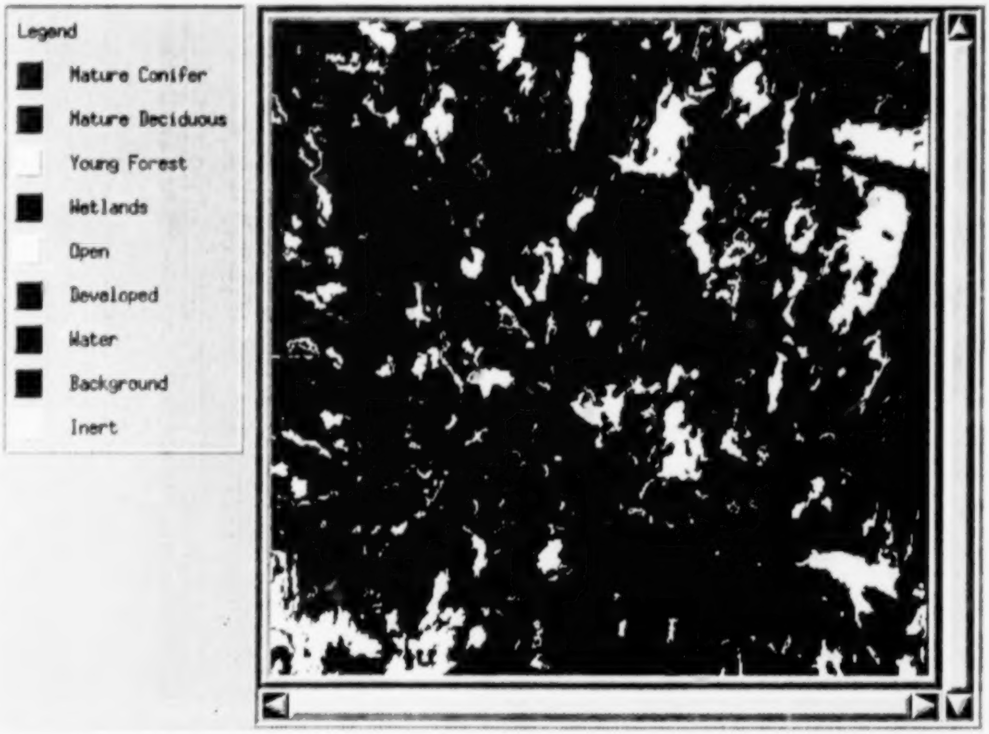

Legend
■ Mature Conifer
■ Mature Deciduous
□ Young Forest
■ Wetlands
□ Open
■ Developed
■ Water
■ Background
□ Inert

Figure 14. Depletion Scenario 2 after 20 years of growth.

6.7 Selecting Indices (LPI 8)

Table 12 outlines the indices we selected to measure the objectives.

Table 12. Indices selected for Case Study 2.

Objective	Indices	Level	Details
Maintain large mature conifer patches with interior after 100 m	Mean patch size (MPS) Largest patch index (LPI) Number of patches (NP) Total core area (Total CA) Number of core areas (NCORE)	Class	Mature conifer class examined
Maximize mature conifer/wetland interface	Contrast-weighted edge density (CWED) Total edge contrast index (TECI)	Class	Mature conifer class examined Mature conifer/wetland interface weighted 1, all others 0
Minimize mature conifer/open areas	Contrast-weighted edge density (CWED) Total edge contrast index (TECI)	Class	Mature conifer class examined Mature conifer/wetland interface weighted 1, all others 0
Ensure connectivity among mature forest patches	Mean nearest-neighbour distance (MNN) Mean proximity index (MPI)	Class	Mature conifer, mature deciduous classes examined

6.8 Setting Parameters (LPI 9)

Since Species X requires large contiguous patches of mature conifer containing interior forest after a 100 m buffer, edge buffer distance was a critical parameter. To eliminate the administrative boundary in the edge calculations, we set the proportion of boundary as edge to 0. In addition, we used edge contrast weighting to examine the explicit edge between the mature conifer class and wetlands and between the mature conifer class and open areas. We ran the contrast-weighted edge statistics twice: once with mature conifer/wetland interfaces weighted as 1 and all others as 0 and once with mature conifer/open interfaces weighted as 1 and all others as 0. We set the proximity distance limit to 500 m and used diagonal neighbours for interior definition.

6.9 Interpretation and Conclusions (LPI 10)

In each depletion scenario we "cut" approximately 1000 ha of mature conifer and 1400 ha of mature deciduous forest, yet the areas of these 2 classes still increased compared with the current condition (Table 13). This increase occurred because a large area of forest classified as *young* in the current condition moved into the mature classes after aging 20 years.

Table 13. Class areas for current condition, natural forest, and both depletion scenarios.

Class	Current	Natural	Cut 1	Cut 2
Mature conifer	6928.00	12615.50	11604.00	11756.50
Mature deciduous	9833.00	16259.00	14881.00	14959.25
Young forest	13179.25	3347.00	3347.00	3347.00
Wetlands	2322.25	2322.25	2322.25	2322.25
Open	2376.00	94.75	2484.25	2253.50
Developed	270.00	270.00	270.00	270.00
Water	5091.50	5091.50	5091.50	5091.50

6.9.1 Objective 1

To determine which scenario best achieves the objective, we compared the depletion scenarios with the current condition, the natural forest, and each other. Table 14 contains the indices that show how well the 4 scenarios maintain large mature conifer patches and interior mature conifer forest. The natural forest scenario resulted in the greatest improvement in indices relevant to Species X habitat; the landscape contained much more old conifer (CA) in larger patches (LPI, MPS) and more core areas (NCA) in combination with more total core area (TCA). In both depletion scenarios, mature conifer increased despite the depletion; however, class characteristics of this class varied. Depletion Scenario 2 met this objective more effectively: Its greater LPI and MPS indicate larger patches and its lower TCA:NCA ratio indicates greater, more contiguous core area.

Table 14. Selected indices for mature conifer class.

Index	Current	Natural	Cut 1	Cut 2
Class area	6928.00	12615.50	11604.00	11756.50
Largest patch index	1.84	3.61	1.92	3.24
Number of patches	199.00	186.00	201.00	172.00
Mean patch size	34.81	67.83	57.73	68.35
Total core area	2541.25	5536.50	4827.50	5309.75
Number of core areas	195.00	277.00	273.00	240.00

6.9.2 Objective 2

To evaluate Objective 2, we examined measures of the pairwise edge between mature conifer and wetlands (Table 15). Scenario 1 resulted in more edge while Scenario 2 produced results similar to the natural condition. Thus we judged Scenario 2 to be more effective at meeting Objective 2.

Table 15. Pairwise edge between mature conifer and wetland areas.

Index	Current	Natural	Cut 1	Cut 2
Contrast-weighted edge density	1.29	2.81	2.76	2.81
Total edge contrast index	2.23	5.01	4.7	4.85

6.9.3 Objective 3

Results for Objective 3 were similar. Scenario 2 resulted in much less conifer/open area edge than Scenario 1 or the current condition.

Table 16. Pairwise edge between mature conifer and open areas.

Index	Current	Natural	Cut 1	Cut 2
Contrast-weighted edge density	1.78	0.12	2.18	0.69
Total edge contrast index	3.08	0.22	3.7	1.19

6.9.4 Objective 4

Scenario 1 resulted in greater connectivity among mature forest patches (lower MNN values). Scenario 2, on the other hand, produced higher values for mean proximity for the conifer forest. This result indicates that although the conifer patches are not connected as well in Scenario 2, the conifer patches are concentrated in clustered groups. It is consistent with the results found for Objective 1.

Table 17. Connectivity measures for mature conifer and mature deciduous areas.

Species	Index	Current	Natural	Cut 1	Cut 2
Conifer	MNN	180.68	137.86	141.72	164.31
	MPI	188.38	882.41	490.35	822.56
Deciduous	MNN	137.44	103.71	108.58	109.9
	MPI	1267.75	7708.65	5323.48	5115.78

6.9.5 Conclusions

Scenario 2 maintains more large, contiguous patches of mature conifer with interior forest than Scenario 1. However, Scenario 1 provides more connectivity of mature forest for Species X. The choice of scenarios will depend on which of these habitat criteria are more critical, as well as other objectives related to timber supply and harvest.

CHAPTER 7

Case Study 3: Monitoring a Time Series

In addition to comparing different management scenarios, LEAP II is useful for monitoring landscape changes over time. This case study illustrates how LEAP II can be used to monitor landscape pattern changes on the same landscape, in this case, under a "natural" successional regime.

To develop a long-term harvest plan, we needed a baseline for how the forest would develop if it were not harvested. We used a basic set of succession rules to project the current forest into the future. For this case study, we did not examine stochastic disturbance (fire, pest, and blowdown), and we assumed that natural succession is the only means of landscape change. This simple set of rules is used to illustrate the process; a true succession projection involves very complex modelling.

7.1 Setting Goals and Objectives (LPI 2)

Before starting LEAP II analysis, we developed a goal and objectives. **Our goal:** Project the forest forward to provide a baseline for comparison with future forest activities. To achieve this goal, we set these **objectives:**

- Apply a basic set of succession rules to the forest cover classes.
- Measure the landscape at regular intervals over a long period to show how landscape patterns vary over time.

7.2 Can LEAP II Be Used Effectively? (LPI 3)

LEAP II can calculate and compare spatial measures for several snapshots of a landscape simultaneously. Thus we determined it would be a wise choice for this analysis.

7.3 Knowing the Dataset (LPI 4)

In addition to knowing the technical details of the dataset, we had to apply knowledge of basic successional pathways for the forest cover types. Based on this knowledge, we developed a set of succession rules to apply to the forest classes (Table 18). Water, wetland, and developed classes remained constant at each time step.

Table 18. Sample succession rules.

Initial Class	Breakup Age Class	Regeneration Class	Regeneration Age Class
Conifer 1	10 (180-200)	Decid 2	2 (20-40)
Conifer 2	10 (180-200)	Decid 1	2 (20-40)
Conifer 3	11 (200-220)	Conifer 3	1 (0-20)
Conifer 4	11 (200-220)	Conifer 4	1 (0-20)
Conifer 5	9 (160-180)	Open 3	1 (0-20)
Conifer 6	10 (180-200)	Decid 2	2 (20-40)
Decid 1	8 (140-160)	Conifer 1	2 (20-40)
Decid 2	8 (140-160)	Conifer 1	2 (20-40)
Decid 3	8 (140-160)	Open 1	1 (0-20)
Open 1 (Decid Cuts)	2 (20-40)	Decid 1	1 (0-20)
Open 2	6 (100-120)	Open 2	1 (0-20)
Open 3 (Conif Cuts)	3 (40-60)	Conifer 1	1 (0-20)

For the classification process, we grouped age classes greater than 6 together as Age Class 6; however, we tracked true age to determine when each stand breaks up.

7.4 What Is the Landscape? (LPI 5)

The analysis was limited to the management unit boundary.

7.5 Base Dataset Creation and Resolution (LPI 6)

To determine each stand's attributes at 20-year timesteps, we projected succession rules forward in the forest inventory database. Using LEAP Builder we generated a base dataset for each timestep from 20 to 200 years in the future. To allow comparison with baseline values from Case Study 1 and future harvest activities, we selected a resolution of 50 m.

7.6 Classification (LPI 7)

After we created a base dataset for each timestep with the forest aging and succession rules applied, we classified each landscape the same way we did in Case Study 1. This allowed us to generate comparable statistics for monitoring and comparing this baseline with future forest conditions. The following landscape images (Figures 15-24) illustrate how the forest will change over time based on our succession rules.

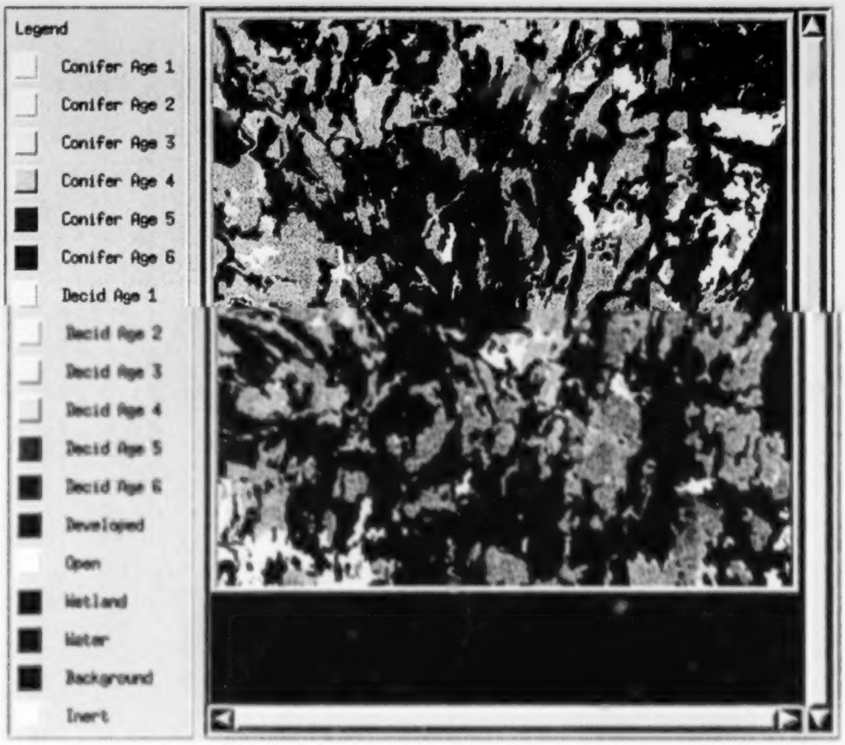
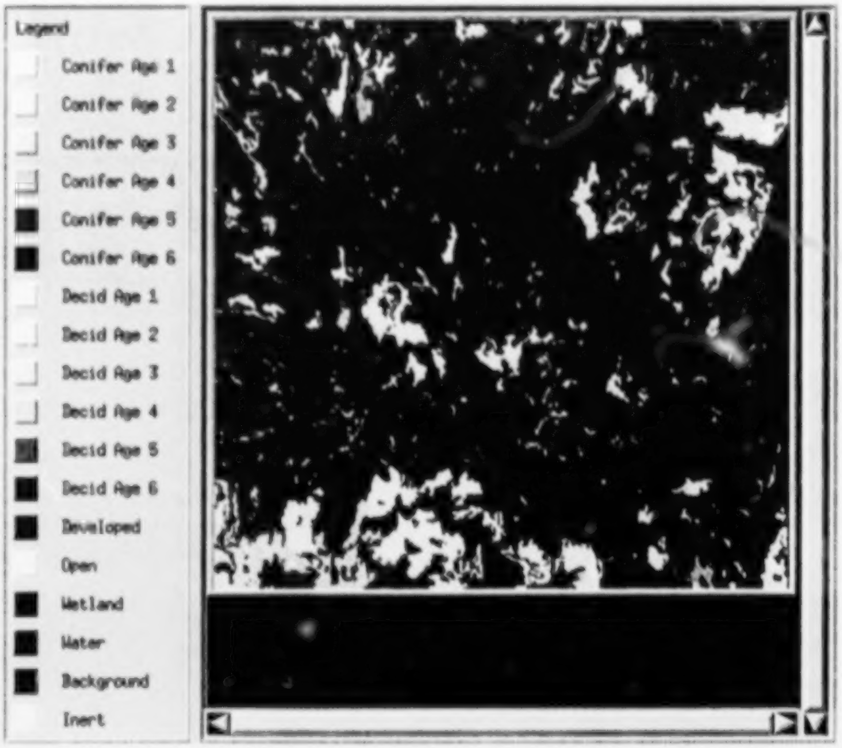

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 15. Sample landscape after 20 years.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Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 16. Sample landscape after 40 years.

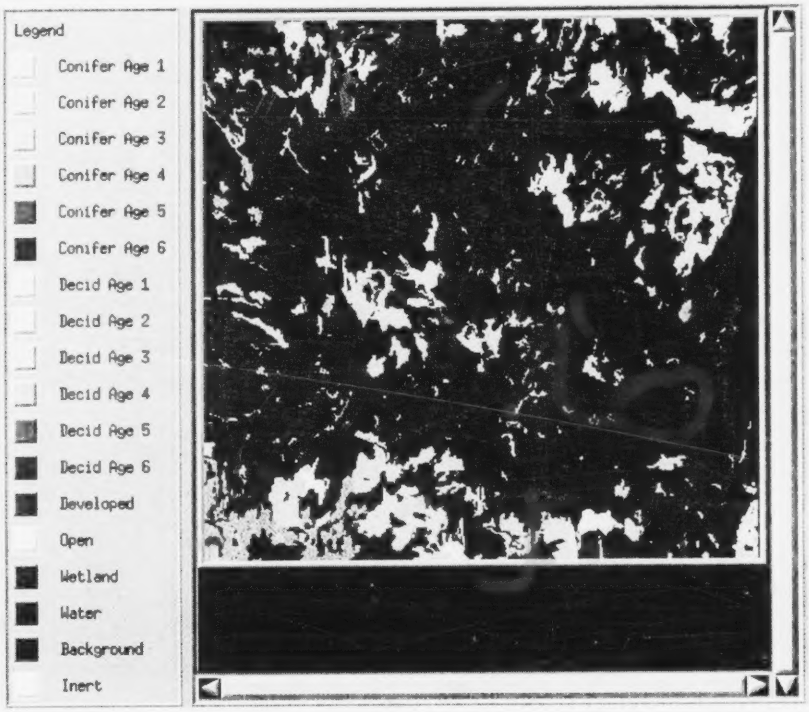

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 17. Sample landscape after 60 years.

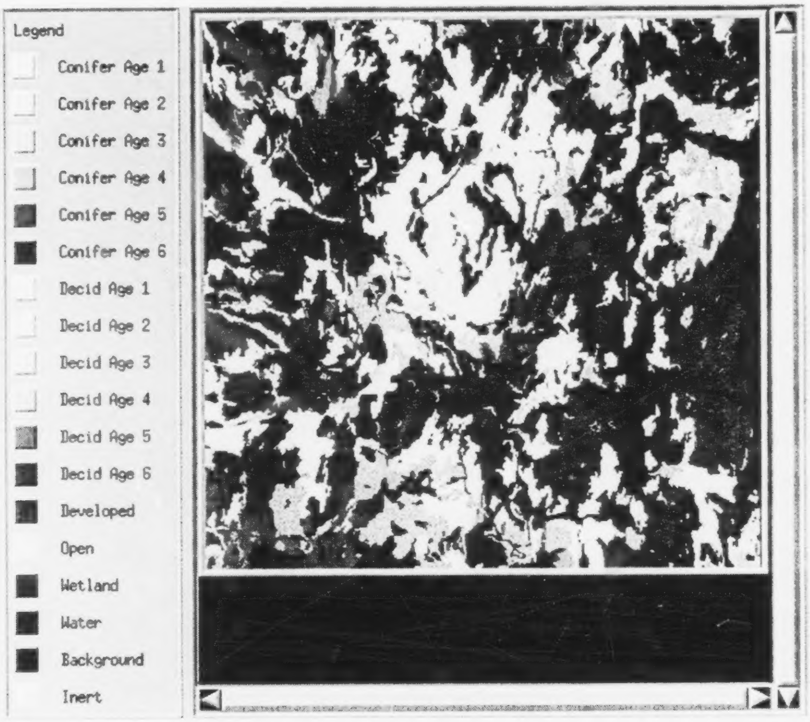

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 18. Sample landscape after 80 years.

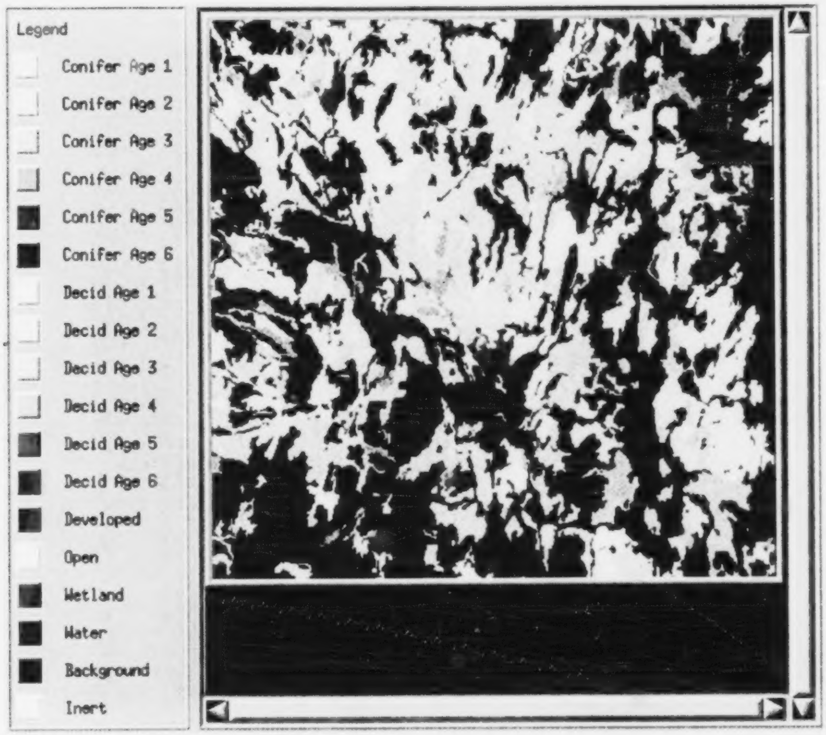

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 19. Sample landscape after 100 years.

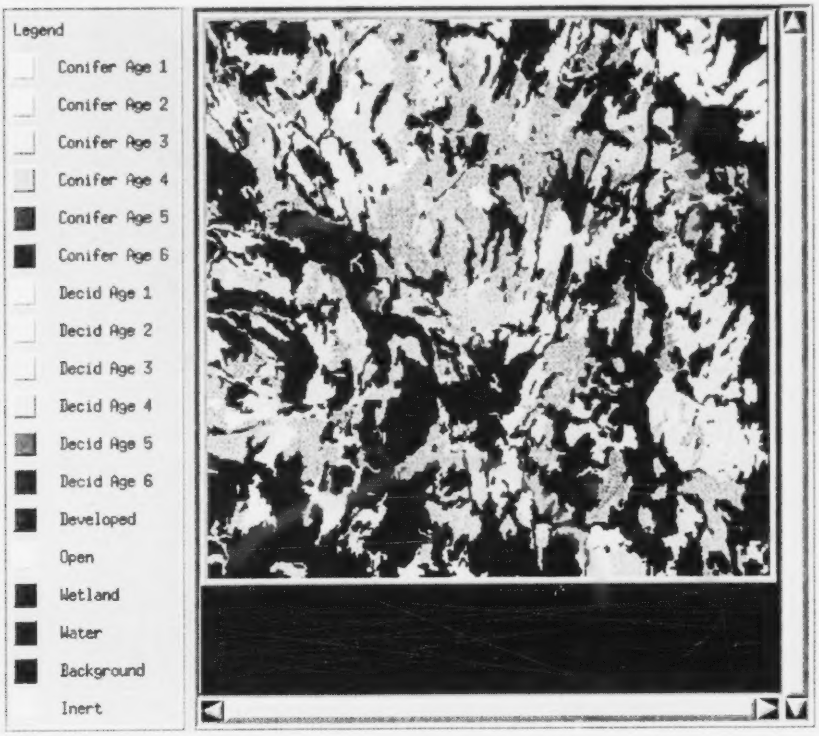

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 20. Sample landscape after 120 years.

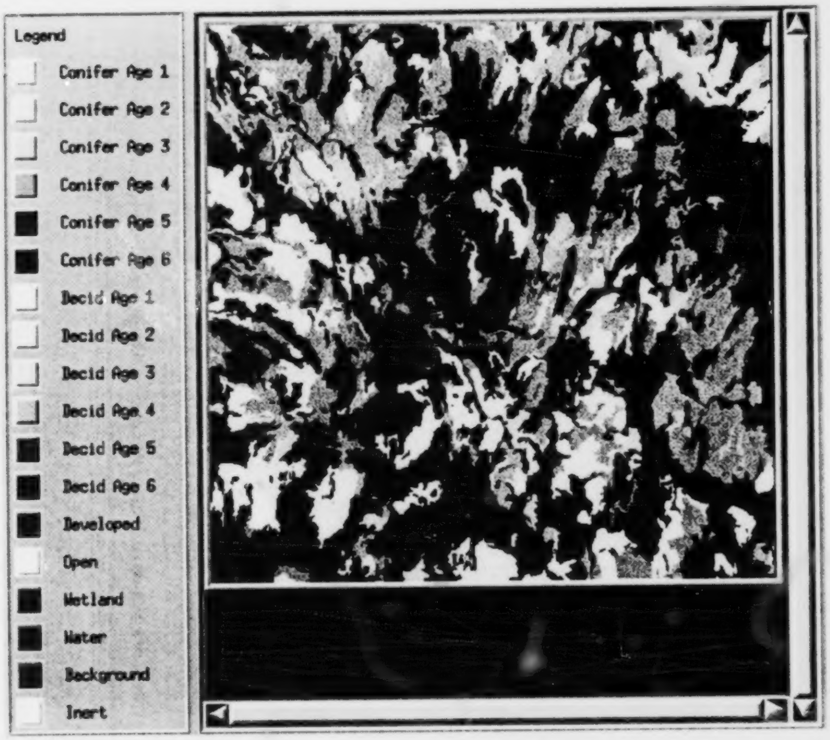

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 21. Sample landscape after 140 years.

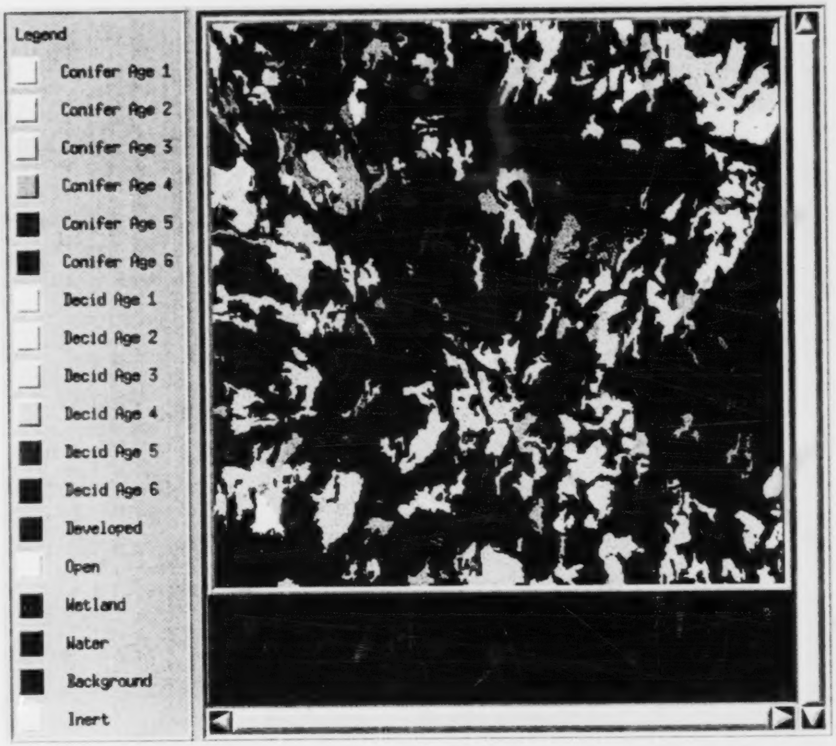

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 22. Sample landscape after 160 years.

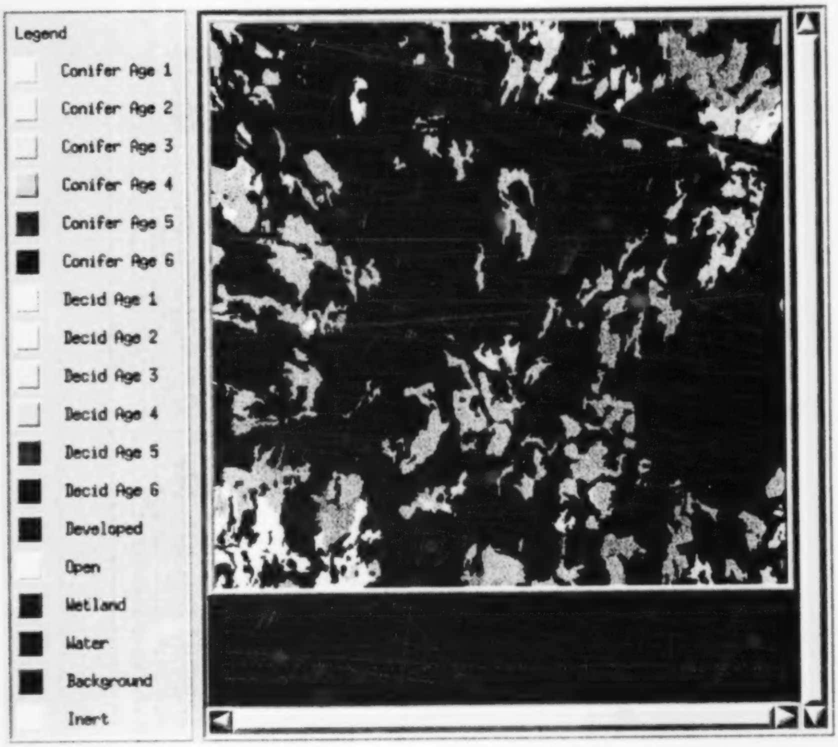

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 23. Sample landscape after 180 years.

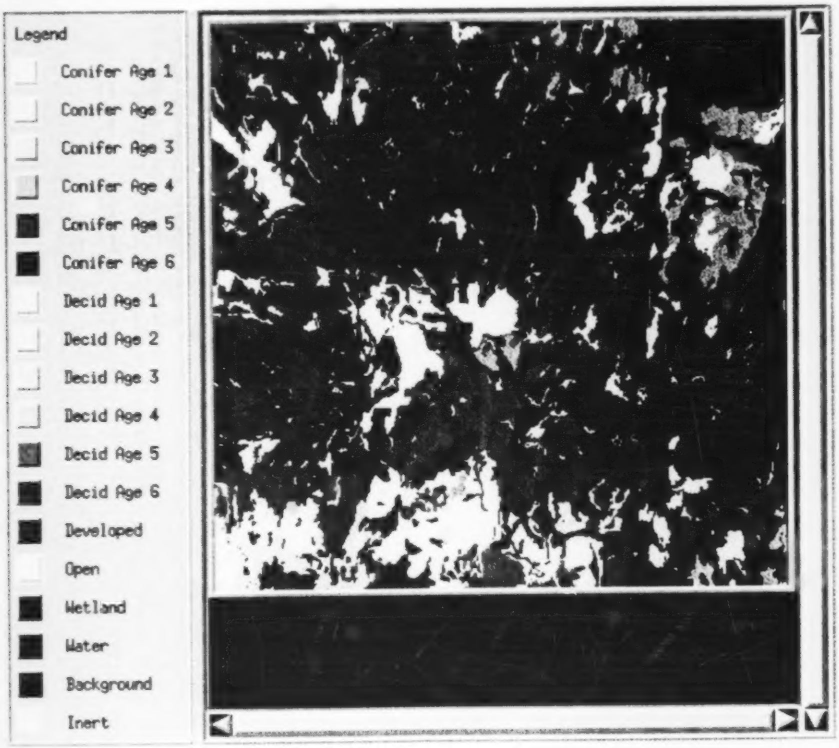

Legend
Conifer Age 1
Conifer Age 2
Conifer Age 3
Conifer Age 4
Conifer Age 5
Conifer Age 6
Decid Age 1
Decid Age 2
Decid Age 3
Decid Age 4
Decid Age 5
Decid Age 6
Developed
Open
Wetland
Water
Background
Inert

Figure 24. Sample landscape after 200 years.

7.7 Selecting Indices (LPI 8)

To allow comparison, we used the landscape measures from Case Study 1.

7.8 Setting Parameters (LPI 9)

Parameters were also set the same as in Case Study 1 (Table 19).

Table 19. Parameters for Case Study 3.

Parameter	Value	Parameter	Value
Edge buffer distance	100 m	Proximity distance limit	500 m
Proportion of boundary as edge	0	Diagonal neighbours used	Yes
Edge contrast weights used?	No		

7.9 Interpretation and Conclusions

With the exception of developed, open, and water areas, class areas change significantly over the time series (Table 20). This information is portrayed graphically in Figures 25 and 26 for the conifer and deciduous forest types.

Table 20. Class area changes through time.

Class	20	40	60	80	100	120	140	160	180	200
ConiferAge1	1052.50	196.50	942.50	0.00	708.25	991.50	0.00	128.00	91.00	0.00
ConiferAge2	697.75	3116.75	3116.75	6762.50	6426.00	713.50	1251.50	1032.25	128.00	2773.50
ConiferAge3	45.00	697.75	697.75	942.50	6762.50	6426.00	713.50	1251.50	1032.25	128.00
ConiferAge4	5687.50	45.00	0.00	3116.75	942.50	6762.50	6426.00	713.50	1251.50	1032.25
ConiferAge5	902.00	5687.50	45.00	697.75	3116.75	942.50	6762.50	6426.00	713.50	1251.50
ConiferAge6	6026.00	6928.00	12412.00	9774.50	8120.25	9456.00	4930.00	11519.50	17247.75	14844.50
DecidAge1	1032.25	0.00	0.00	141.25	29.25	89.75	0.00	57.75	0.00	0.00
DecidAge2	260.00	1032.25	0.00	2682.50	1785.00	931.25	5558.25	45.00	755.50	3116.75
DecidAge3	63.00	260.00	1032.25	0.00	2682.50	1785.00	931.25	5558.25	45.00	755.50
DecidAge4	6426.00	63.00	260.00	1032.25	0.00	2682.50	1785.00	931.25	5558.25	45.00
DecidAge5	6852.25	6426.00	63.00	260.00	1032.25	0.00	2682.50	1785.00	931.25	5558.25
DecidAge6	2980.75	7627.50	13278.25	6489.00	323.00	1292.25	1032.25	2682.50	4467.50	2716.25
Developed	270.00	270.00	270.00	270.00	270.00	270.00	270.00	270.00	270.00	270.00
Open	291.25	236.00	468.75	417.25	388.00	243.50	243.50	185.75	94.75	94.75
Wetland	2322.25	2322.25	2322.25	2322.25	2322.25	2322.25	2322.25	2322.25	2322.25	2322.25
Water	5091.50	5091.50	5091.50	5091.50	5091.50	5091.50	5091.50	5091.50	5091.50	5091.50

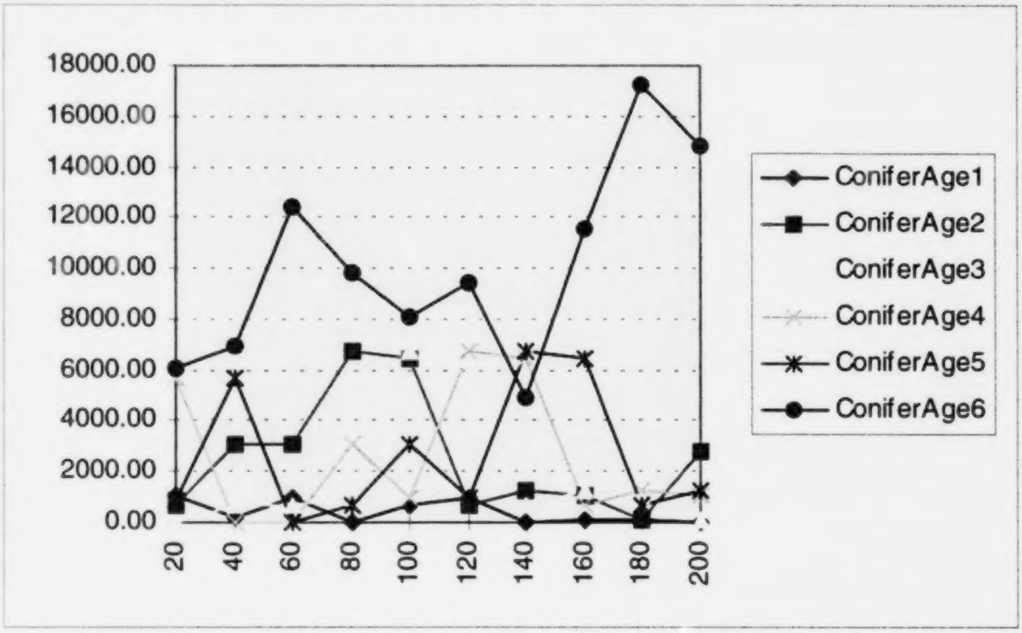


Figure 25. Class areas changes for conifer forest types through time.

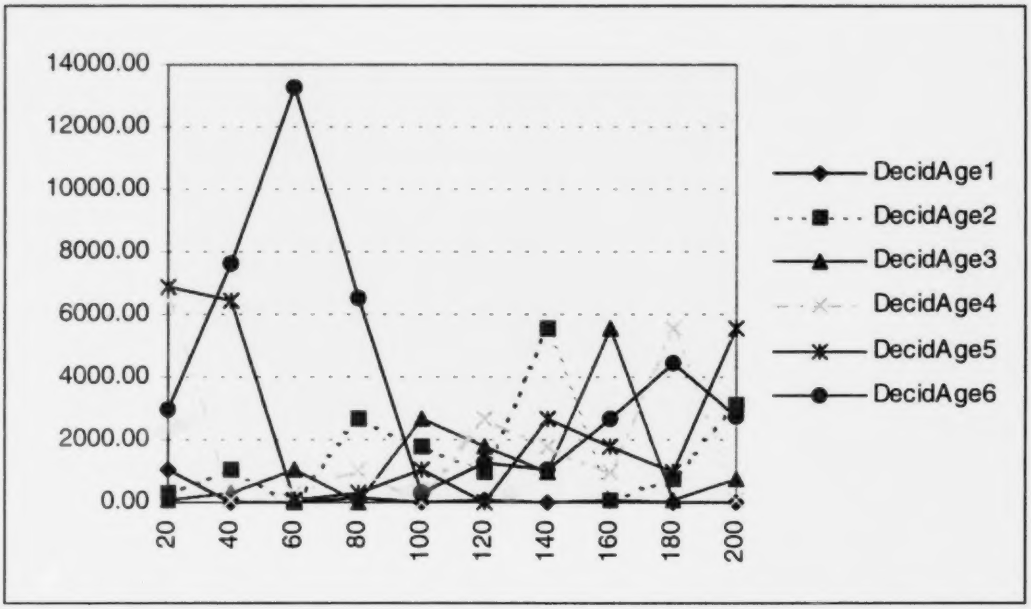


Figure 26. Class areas changes for deciduous forest types through time.

Table 21 contains the landscape index values over the 200-year period. Many of the indices show a wave pattern. Approaching year 60, the forest becomes less fragmented. Core areas increase (Total CA), patches become larger (MPS) and less numerous (NP), and there is less edge (TE). At the same time, both components of diversity (richness and evenness) decrease, indicating that some forest types have been lost and that the distribution of area between types is less balanced. These trends reverse between year 60 and year 140 and return toward year 180, forming a wave pattern. The peaks and valleys of this wave may indicate a range of natural variation for this landscape.

Table 21. Selected landscape index values through time.

Index	20	40	60	80	100	120	140	160	180	200
LA	40000	40000	40000	40000	40000	40000	40000	40000	40000	40000
NP	1617	1538	1328	1520	1577	1451	1562	1369	1168	1387
PD	4.04	3.85	3.32	3.8	3.94	3.63	3.9	3.42	2.92	3.47
MPS	24.74	26.01	30.12	26.32	25.36	27.57	25.61	29.22	34.25	28.84
Total edge	2482600	2438700	2241650	2420500	2443850	2388200	2458600	2353800	2134400	2225050
Edge den	62.06	60.97	56.04	60.51	61.1	59.71	61.47	58.85	53.36	55.63
Total CA	14250	14538.75	16126	14683	14514	14819	14313.75	14985	16778	16318.25
Prox dist	304.9	286.2	303.3	292.6	306	323.1	301.5	317.8	339.5	302.3
Prox area	175.29	207.1	497.18	215.03	178.07	272.24	188.24	349.8	1451.91	558.15
Heter Shan	2.25	2.12	1.75	2.13	2.24	2.21	2.3	2.13	1.83	1.99
Heter Simp	0.87	0.86	0.77	0.85	0.87	0.86	0.88	0.84	0.76	0.81
Class rich	16	15	13	14	15	15	14	16	15	14
Cls r den	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Even Shan	0.81	0.78	0.68	0.81	0.83	0.82	0.87	0.77	0.68	0.75
Even Simp	0.93	0.92	0.83	0.92	0.93	0.92	0.95	0.9	0.81	0.87
MSIEI	0.75	0.73	0.57	0.73	0.75	0.73	0.81	0.67	0.53	0.62
Intersper	79.04	75.21	65.43	78.41	81.32	78.07	84.19	73.19	65.38	73.68

CHAPTER 8

Case Study 4: Spread Analysis

This case study illustrates the spread analysis capabilities of LEAP II. Our forest company had to meet a new requirement to analyze how the planned harvest would affect the movement patterns of Species Y. In addition, to develop a haul road plan, we had to identify potential high-traffic corridors for Species Y.

Known characteristics of Species Y:

- Has a typical home range of 5000 ha.
- Uses mature hardwood forest for transit corridors between denning and feeding areas.
- Must be able to access a number of feeding areas, stays mobile, feeds during the day.
- Is very sensitive to large open areas and human disturbance/access (allows hunting pressure and ease of travel for predators).
- Avoids young conifer and wetlands and will not travel through open water.
- Will not expend more than 400 units of energy per day to feed.

8.1 Setting Goals and Objectives (LSA 2)

To meet these new requirements, we developed the following **goal**: Analyze the connectivity of the landscape under both harvest scenarios to identify potential conflicts with planned harvest blocks and proposed haul roads. To achieve this goal, we set the following **objectives**:

- Identify area that will be accessed in 1 day's feeding expenditure.
- Identify all home locations that are not connected to more than 1 feeding location within 1 day's energy expenditure limit.
- Identify potential connectivity paths to avoid in haul road plan.

8.2 Can LEAP II Be Used Effectively? (LSA 3)

We decided that the spread analysis module of LEAP II was an appropriate choice to meet our goal and objectives because it could:

- Analyze spatial movement across the landscape.
- Deal with movement from a starting point source (den location) to several other locations (feeding areas) simultaneously.
- Provide a simple means of classifying the landscape into relative *friction values* based on class attributes.

8.3 Knowing the Dataset (LSA 4)

As with the other case studies, we had a thorough understanding of database construction. For this case study, we had to translate broad cover types over various ages into a surface of movement. We used the dominant cover and age class attributes generated for Case Study 1 to build a dataset for LEAP II. We then determined that we needed more information about den and feeding point locations. We knew that our management unit contained 3 den locations and 7 prime feeding areas; the company biologists used GPS to identify all of these points. Using the lower left coordinate, extent (rows and columns), and resolution (50 m), of the LEAP II base dataset, we converted these points from real coordinates (in this case UTM) to row and column values. This conversion allowed us to enter these points into LEAP II for analysis.

8.4 What Is the Landscape? (LSA 5)

For this case study, the management unit is our landscape. This extent of 40000 ha is reasonable, given that Species Y has a typical home range of 5000 ha.

8.5 Database Creation and Resolution (LSA 6)

For this case study, we used the same attributes as the first 2 case studies. We used LEAP Builder to generate a base dataset at a resolution of 50 m for each depletion scenario from Case Study 2. This resolution represents a reasonable unit of movement within the typical 5000 ha home range.

8.6 Classification (LSA 7)

Although detailed cover type and age information was available, we did not have enough information to develop relative friction values for all combinations. We knew that Species Y prefers movement through mature hardwood; avoids open areas, disturbance areas, young conifer, and wetlands; and won't travel through water at all. Based on this information, we classified the base dataset for each scenario (Table 22).

Table 22. Landscape classification for spread analysis.

Class	Cover type	Age Classes
Mature Deciduous	Decid 1, 2, 3	4, 5, 6
Young Deciduous	Decid 1, 2, 3	1, 2, 3
Mature Conifer 3	Conifer 3	4, 5, 6
Other Mature Conifer	Conifer 1, 2, 4, 5, 6	4, 5, 6
Young Conifer	Conifer 1, 2, 4, 5, 6	1, 2, 3
Wetlands	Wetland 1, 2, 3	N/A
Open	Open 1, 2, 3	All
Developed	Developed 1	N/A
Water	Water	N/A

Figures 27 and 28 illustrate the results of applying this classification to the 2 depletion scenario base datasets from Case Study 2. These figures also show the 3 den locations and 7 feeding areas.

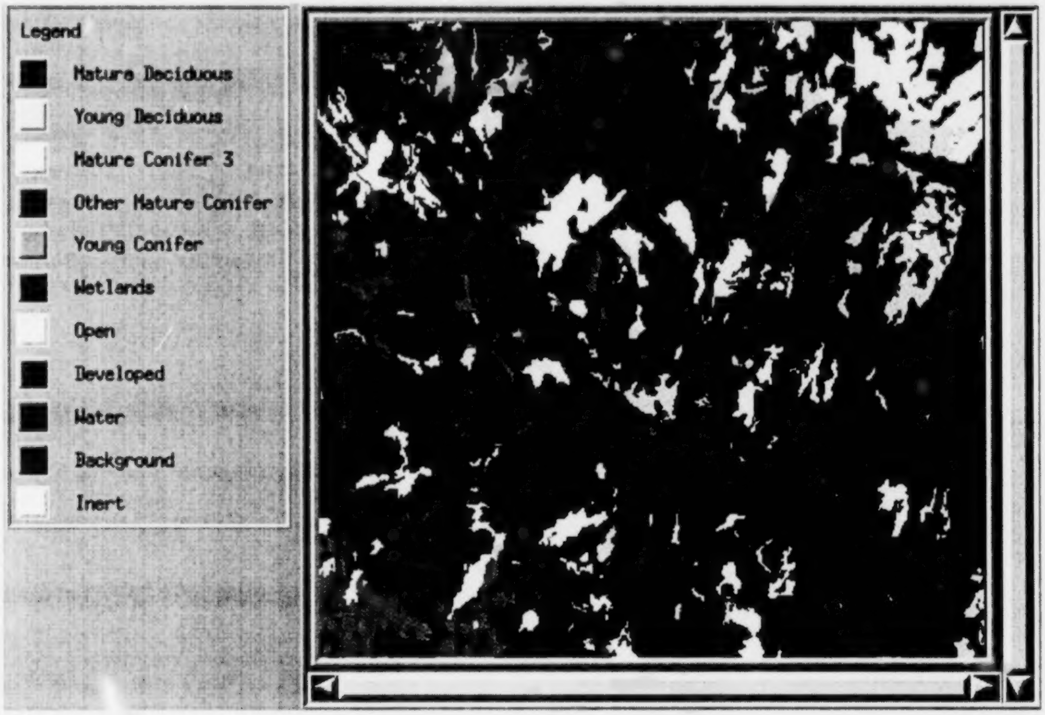

Legend
■ Mature Deciduous
□ Young Deciduous
□ Mature Conifer 3
■ Other Mature Conifer
□ Young Conifer
■ Wetlands
□ Open
■ Developed
■ Water
■ Background
□ Inert

Figure 27. Depletion Scenario 1 (● = den location; ■ = feeding area).

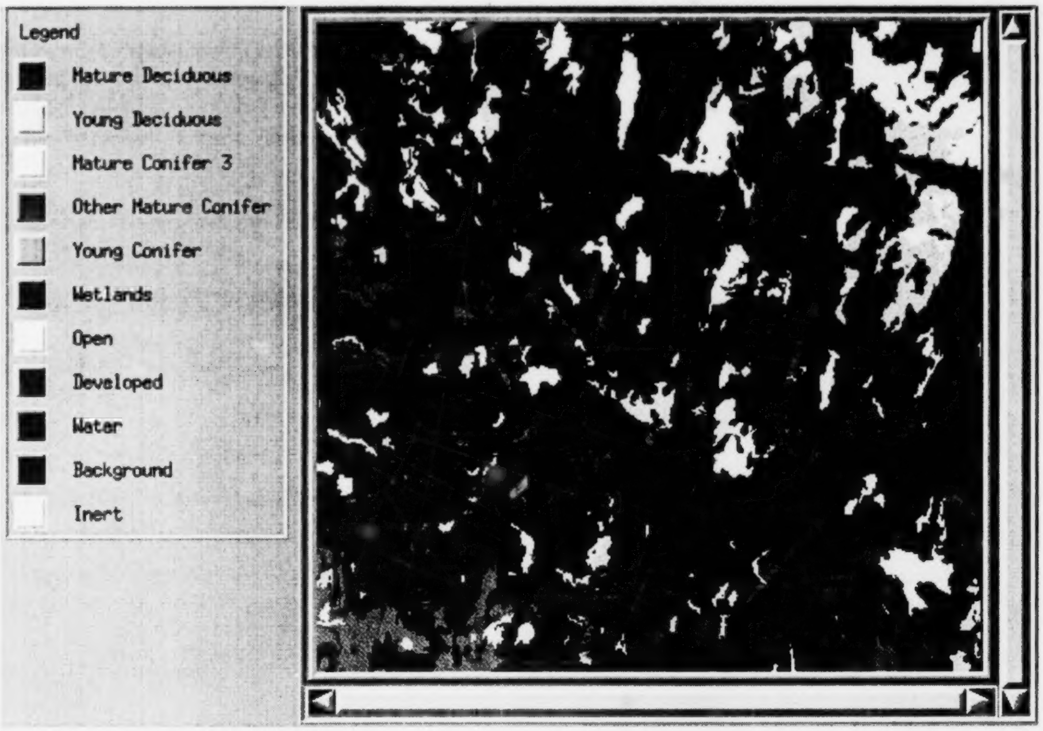

Legend
■ Mature Deciduous
□ Young Deciduous
□ Mature Conifer 3
■ Other Mature Conifer
□ Young Conifer
■ Wetlands
□ Open
■ Developed
■ Water
■ Background
□ Inert

Figure 28. Depletion Scenario 2 (● = den location; ■ = feeding area).

8.7 Assigning Friction Values (LSA 8)

After consulting a company biologist, we determined that movement through each 50 m unit of the preferred mature deciduous cover costs Species Y a single unit of energy. From this information we developed a set of friction values related to the relative energy cost to move through each of the cover types defined in the classification process (Table 23). We set the values for open areas very high to reflect Species Y's aversion to this cover type. We set the values for developed areas and water bodies even higher to bar movement through these areas (value of 200 was based on threshold value outlined in Section 8.9). The maps below (Figures 29 and 30) show the friction surface for each depletion scenario based on these values.

Table 23. Friction values assigned to landscape classes.

Class	Friction Value	Class	Friction Value
Mature Deciduous	1	Wetlands	10
Young Deciduous	4	Open	50
Mature Conifer 3	2	Developed	200
Other Mature Conifer	3	Water	200
Young Conifer	7		

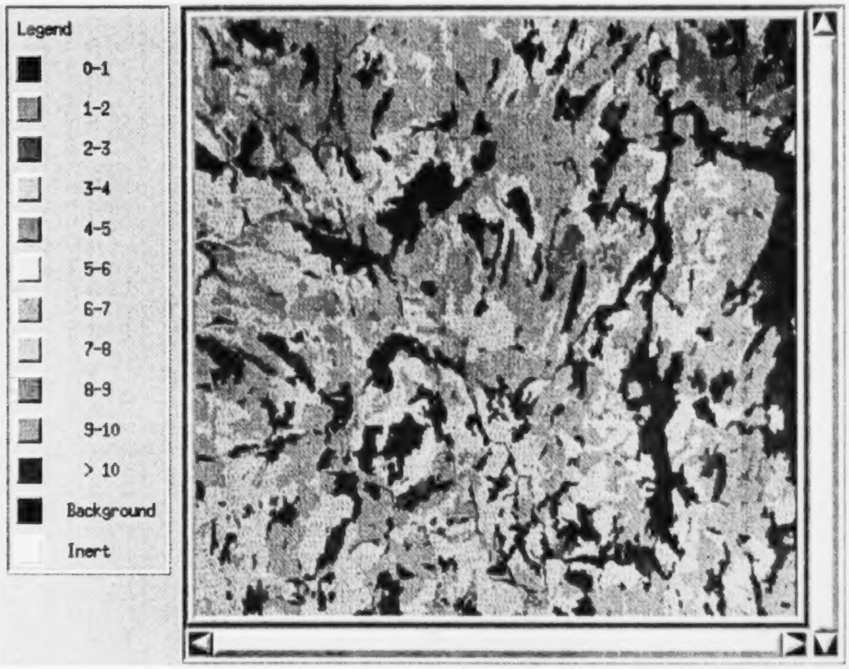


Figure 29. Friction surface for Depletion Scenario 1.

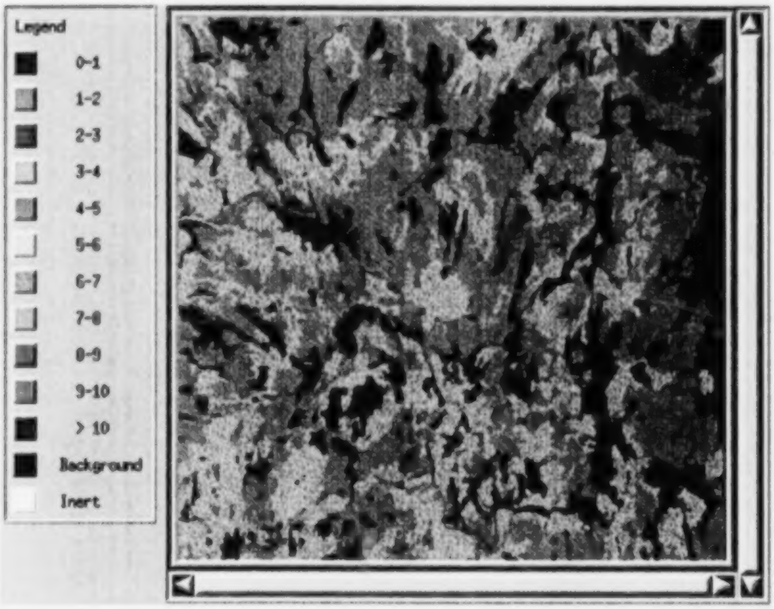


Figure 30. Friction surface for Depletion Scenario 2.

8.8 Selecting Source Points (LSA 9)

For this analysis, we needed source points for the den locations and feeding areas. These points were illustrated on the classified landscapes shown earlier. We developed a series of source point files to complete the analyses for each of the objectives. For the first objective, we needed only the den locations to map accessible landscape areas. To map the linkages between each den and each feeding area, we created a source point file for each den/feeding area combination (after running the analysis for Objective 1, we eliminated combinations that have a feeding area that is too distant from the den). To meet Objective 3, we created a source point file that contains all of the dens and all of the feeding areas, so we could analyze the connectivity among these locations.

8.9 Setting Threshold Values (LSA 10)

We based the threshold value on the energy expenditure limit of Species Y for 1 day, i.e., 400 units of energy. To identify areas that can be accessed in 1 day's feeding limit and feeding sites that are connected to each den, we used a threshold value of 200. This value limited the search to areas that Species Y can access and still have sufficient energy to return to the den. We used this same threshold value to map potential connectivity paths to avoid in the haul road plan.

8.10 Interpretation and Conclusions (LSA 11)

8.10.1 Objective 1

Our first objective was to identify all areas of the landscape that Species Y can access from the den locations within the 1-day energy expenditure limit. We used the spread analysis module to map the spread from the den locations based on the friction surface for each depletion scenario. The results of these analyses are presented in Figures 31 and 32. Each band identifies an area that Species Y can access within the energy expense shown in the legend, ending at our threshold value of 200.

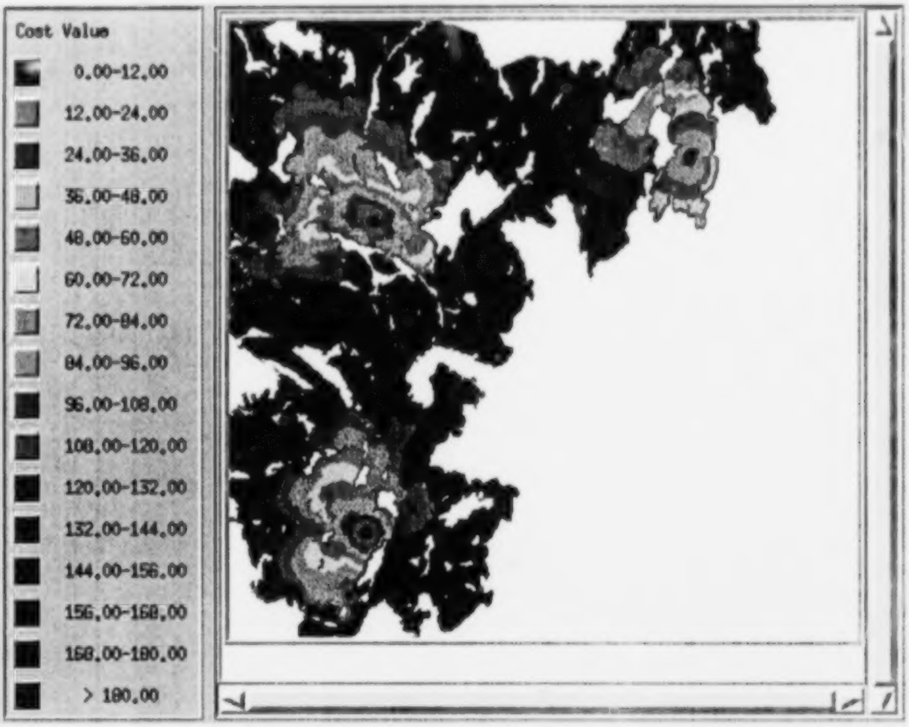

Cost Value
0.00-12.00
12.00-24.00
24.00-36.00
36.00-48.00
48.00-60.00
60.00-72.00
72.00-84.00
84.00-96.00
96.00-108.00
108.00-120.00
120.00-132.00
132.00-144.00
144.00-156.00
156.00-168.00
168.00-180.00
> 180.00

Figure 31. Results of spread analysis for Depletion Scenario 1.

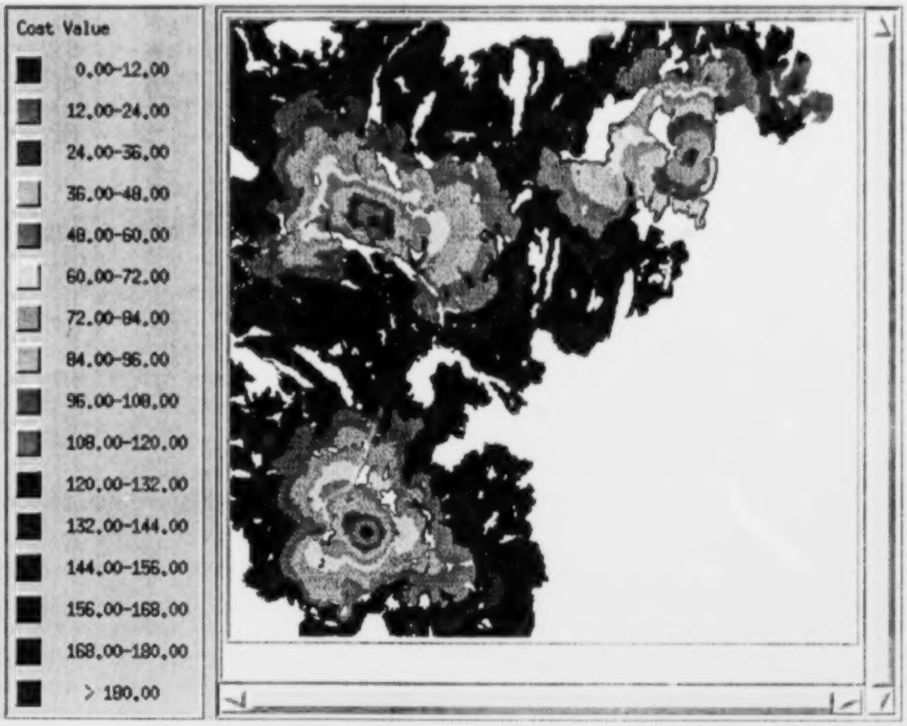

Cost Value
0.00-12.00
12.00-24.00
24.00-36.00
36.00-48.00
48.00-60.00
60.00-72.00
72.00-84.00
84.00-96.00
96.00-108.00
108.00-120.00
120.00-132.00
132.00-144.00
144.00-156.00
156.00-168.00
168.00-180.00
> 180.00

Figure 32. Results of spread analysis for Depletion Scenario 2.

8.10.2 Objective 2

Based on the results of the spread analysis, we eliminated all den/feeding area combinations that could not be linked. We used LEAP II's corridor analysis module to identify the linked pairs among the remaining combinations. Table 24 summarizes the feeding areas that are connected to each den for each depletion scenario.

Table 24. Summary of connectivity between dens and feeding locations for each depletion scenario.

Feeding Location	Home Location 1		Home Location 2		Home Location 3	
	DS 1	DS 2	DS 1	DS 2	DS 1	DS 2
1	No	Yes	No	No	No	No
2	No	Yes	No	Yes	No	No
3	No	No	Yes	Yes	No	No
4	No	No	Yes	Yes	No	Yes
5	No	No	No	No	No	No
6	No	No	No	No	No	Yes
7	No	No	No	No	No	Yes
Total	0	2	2	3	0	3

Figures 33 and 34 illustrate the results of these analyses for the connected pairs. In each case, the outermost band shows the connection area at our threshold value of 200 energy units. Bands within show connections existing at lower energy levels. These connections are therefore stronger than those that are connected only at the threshold limit.

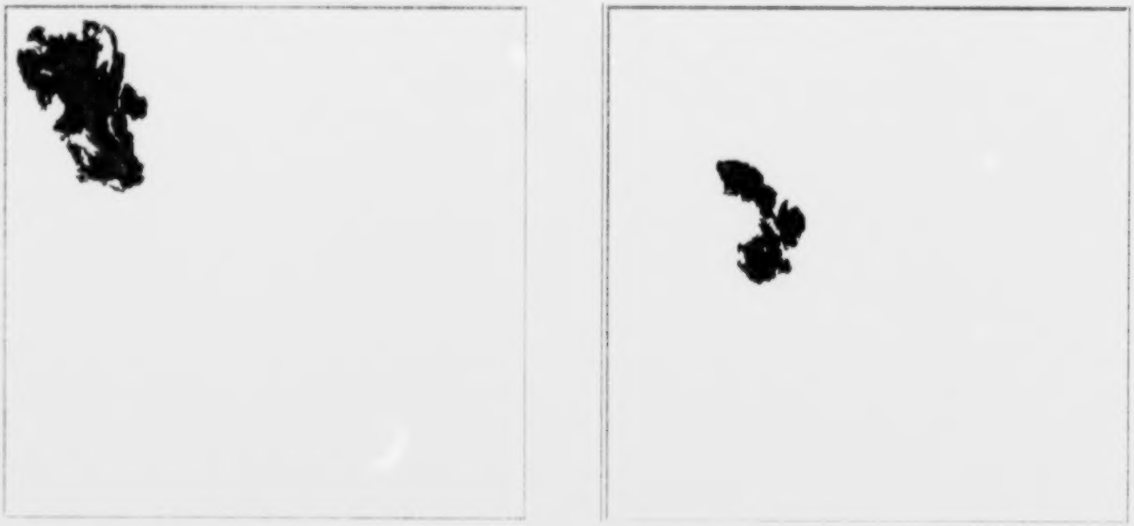


Figure 33. Connected dens and feeding locations for Depletion Scenario 1.

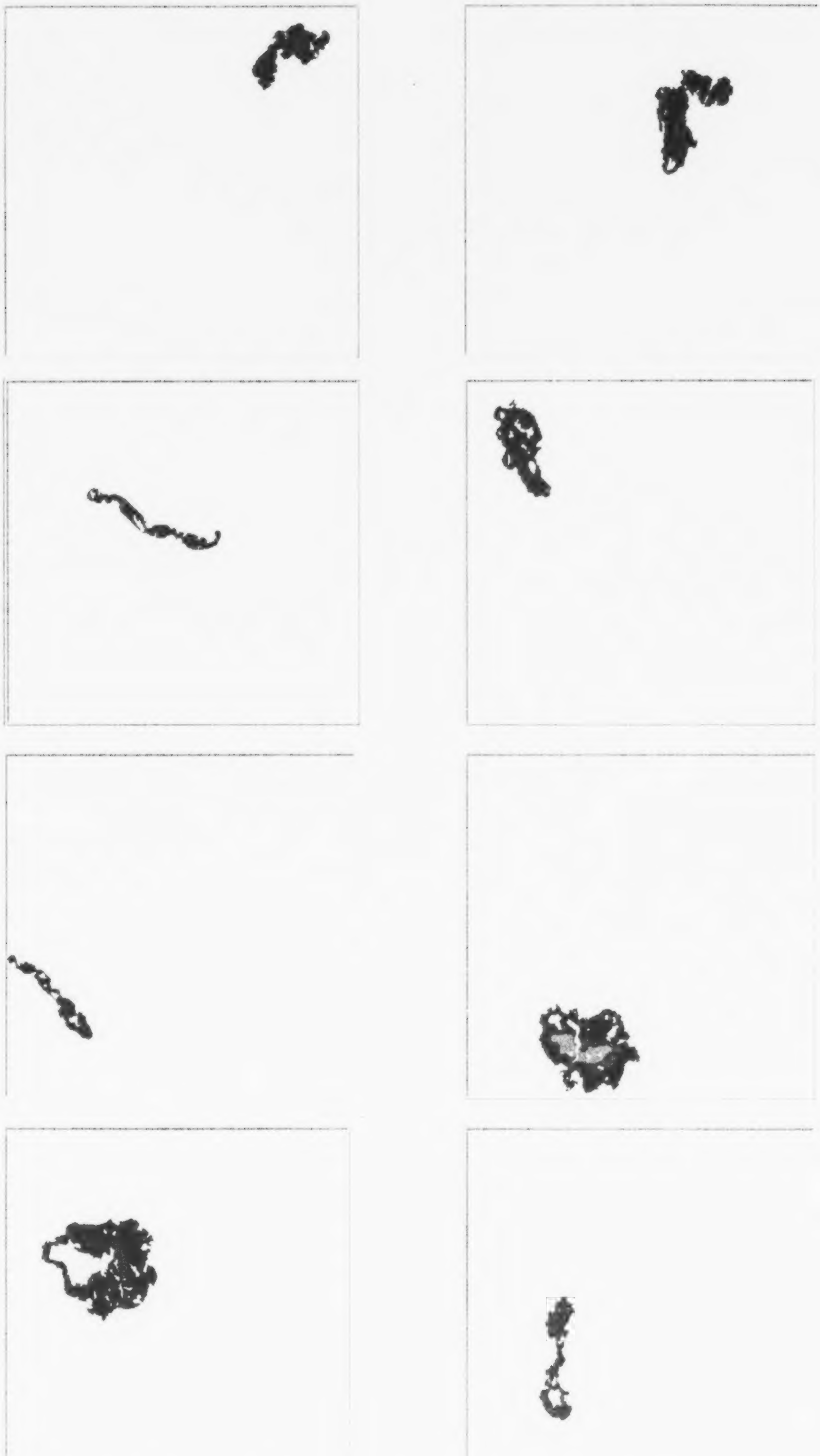


Figure 34. Connected dens and feeding locations for Depletion Scenario 2.

8.10.3 Objective 3

Using LEAP II's linkage analysis module, we identified the connectivity network among all of the den and feeding locations for each depletion (Figures 35 and 36). Our haul road plan should avoid these areas.

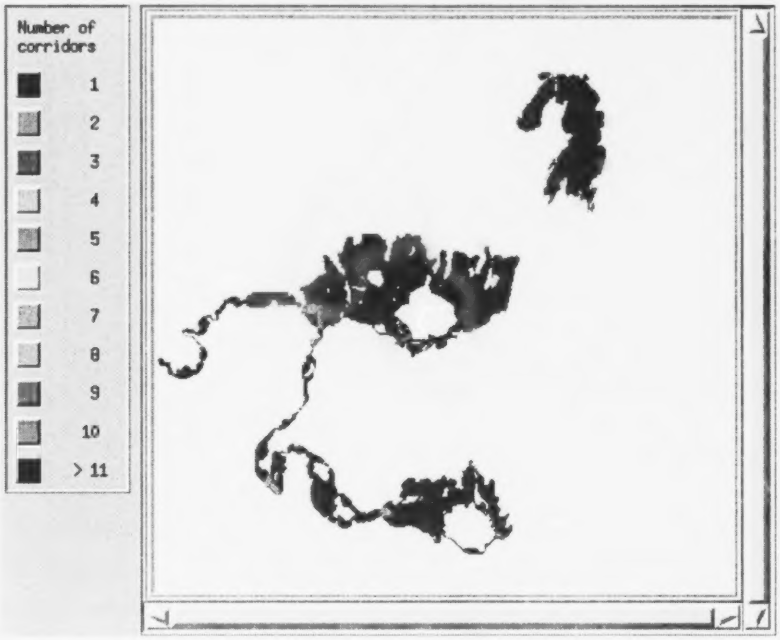

Number of corridors
1
2
3
4
5
6
7
8
9
10
> 11

Figure 35. Connectivity concern area for Depletion Scenario 1.

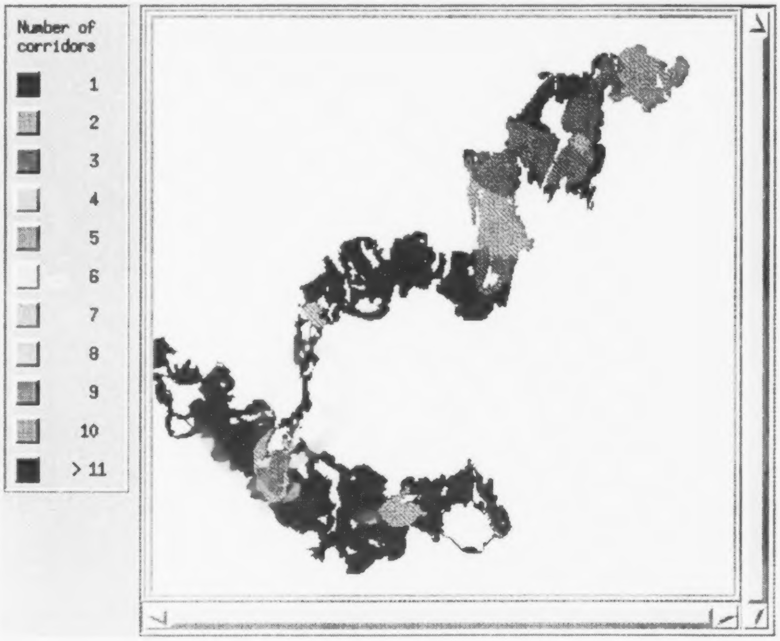

Number of corridors
1
2
3
4
5
6
7
8
9
10
> 11

Figure 36. Connectivity concern area for Depletion Scenario 2.

8.10.4 Conclusions

The first depletion scenario does not provide good connectivity potential for Species Y. Only 2 feeding sites are connected to just 1 of the den locations within a single day's energy expenditure limit. Scenario 2 shows linkages between at least 2 feeding sites for each den location.

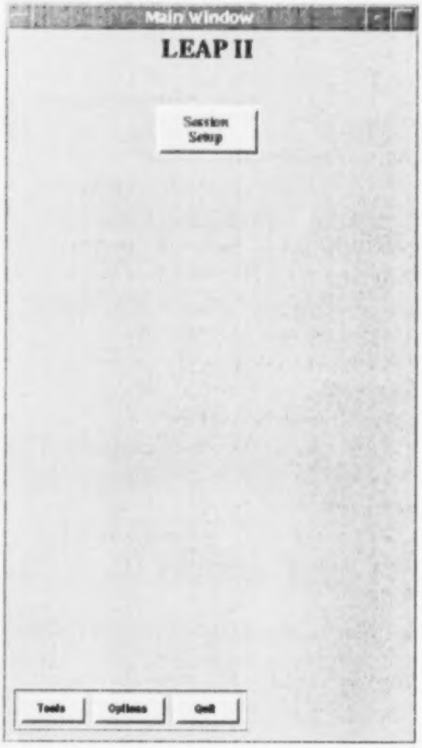
CHAPTER 9

Getting Started With LEAP II

To start LEAP II, type *leap2* at the Unix prompt and press *<Enter>*. For example:

/usr/users/sally/>leap2

where */usr/users/sally/>* is the Unix prompt. The LEAP II ***Main Window*** will open.



The ***Main Window*** provides access to all functions and features of LEAP II. It remains on screen for the entire session.

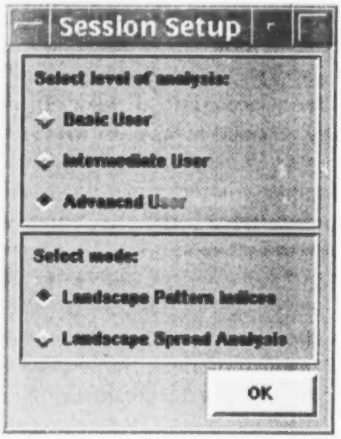
As you conduct your analysis and modelling, the ***Main Window*** will serve as a guide by displaying and highlighting buttons that indicate your next steps. Using the mouse, you can move the ***Main Window*** around the screen for easy access to other LEAP II windows.

At the bottom of the ***Main Window*** are 3 buttons: ***Tools***, ***Options***, and ***Quit***. Click on ***Tools*** to access the tools available during the session to help with the analysis (for a complete list, see Chapter 12). Click on ***Options*** to access and set program options.

To begin a LEAP II session, click on ***Session Setup***.

9.1 Setting up the Session

To set the user level and mode of analysis for the current session, click on ***Session Setup*** on the ***Main Window***.



Select level of analysis:

- ○ Basic User
- ○ Intermediate User
- ● Advanced User

Select mode:

- ● Landscape Pattern Indices
- ○ Landscape Spread Analysis

Select 1 of the 3 user levels of analysis by clicking on the appropriate button: ***Basic User***, ***Intermediate User***, or ***Advanced User***.

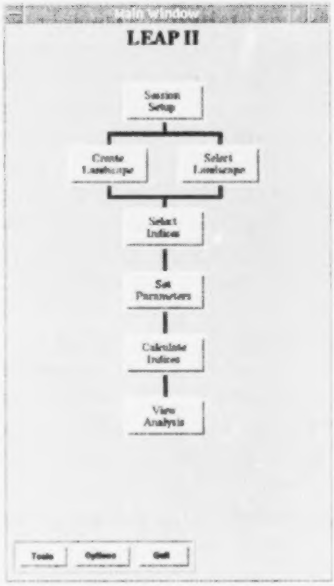
The user level affects the number and type of indices LEAP II will generate. If you select ***Advanced User***, you must also select the mode of analysis for the session: ***Landscape Pattern Indices*** or ***Landscape Spread Analysis***.

To close the ***Session Setup*** box and begin the session, click on ***OK***. The ***Main Window*** will display more buttons, which will vary depending on which mode you selected.

CHAPTER 10

Calculating Landscape Pattern Indices

If you selected the ***Landscape Pattern Indices*** mode, *the **Main Window*** will display the buttons shown at right (for information on the ***Landscape Spread Analysis*** mode, see Chapter 11). The buttons and their connections represent the steps you will take to carry out an analysis. Each button activates a component of LEAP II that allows you to make certain selections or set parameters to configure the analysis. Not all buttons will be active initially, but as you work through an analysis, they activate as needed to indicate the next step.

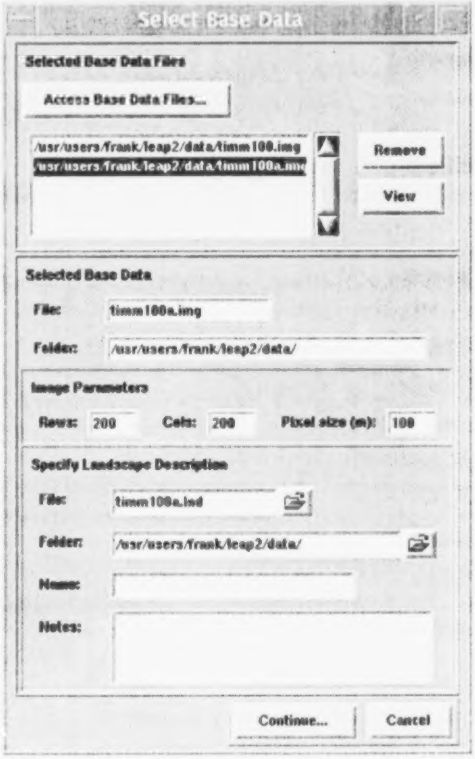

Main Window
LEAP II
Session Setup
Create Landscape
Select Landscape
Select Indices
Set Parameters
Calculate Indices
View Analysis
Tools
Options
Quit

To begin, click on ***Create Landscape*** or ***Select Landscape***, depending on whether you want to create a new landscape or use an existing one.

A *landscape* represents a study area that has been classified, typically using a base dataset of forest stands and a user-defined classification scheme.

10.1 Creating a New Landscape

To create a new landscape, click on ***Create Landscape*** on the ***Main Window***. The ***Select Base Data*** window will open to allow you to select 1 or more base data files from which to create landscapes (see Appendix II). You can specify the file name and folder for each landscape, as well as provide a descriptive name and notes.


Select Base Data
Selected Base Data Files
Access Base Data Files...
Remove
View
Selected Base Data
Image Parameters
Specify Landscape Description
Continue...
Cancel

/usr/users/frank/leap2/data/timm100.img
/usr/users/frank/leap2/data/timm100a.img

File: timm100a.img
Folder: /usr/users/frank/leap2/data/

Rows: 200 Cols: 200 Pixel size (m): 100

File: timm100a.lnd
Folder: /usr/users/frank/leap2/data/
Name:
Notes:

To select a base data file, click on *Access Base Data Files*. *The **File Cabinet*** will open. Select 1 or more data files and then close the cabinet by clicking on ***OK***. The list box will display the data file names. To remove a selected base data file from the list, click on its name and select ***Remove***. To view a base data file image, click on its name and select ***View***. If you select 2 or more base data files, the window will display information that corresponds to the file currently highlighted in the list box.

For each selected base data file, LEAP II will create default file and folder names for the corresponding landscape files you create. The ***Specify Landscape Description*** box lists these files and folders. To change a default landscape file or folder name, click on the folder icon to access the ***File Cabinet*** or delete the file or folder name and key in a different one. For each landscape you can add a descriptive name and notes.

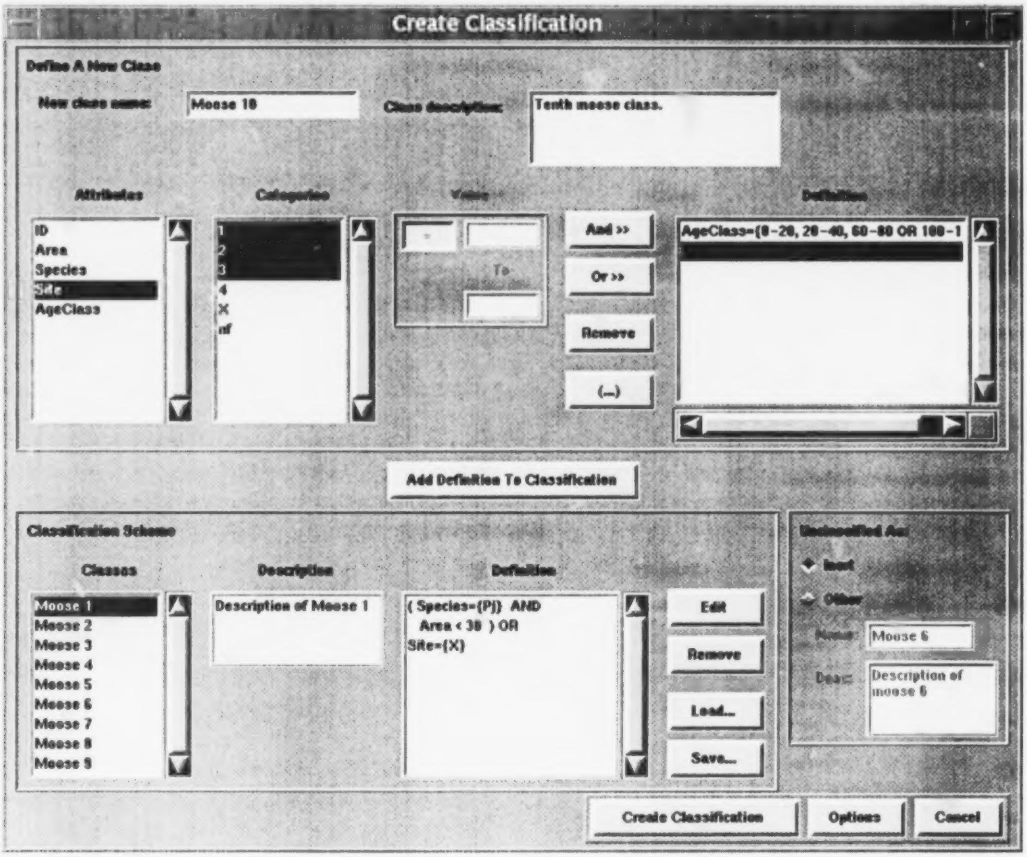
After you select data files, click on ***Continue*** to open the ***Create Classification*** window. If 1 of the specified landscape files already exists, you will be prompted to confirm that you wish to overwrite it. Click on ***No*** to return to the ***Select Base Data*** window, where you can rename the file.

10.1.1 Creating a Classification Scheme

The *Create Classification* window allows you to create a classification scheme with which to classify polygons using the attributes available in the base dataset. To define a class:

- Enter the name of the class and a class description.
- Select the combination of attributes and values that describe the class.
- Add the new class to the classification scheme.

Repeat these steps for each class in the classification scheme (detailed instructions for creating a class definition follow). Define classes in the *Define A New Class* box. The *Classification Scheme* box displays the current classification.


Create Classification
Define A New Class
Attributes
ID
Area
Species
Site
AgeClass
Categories
1
2
3
4
X
nf
Value
To
And >>
Or >>
Remove
(...)
Definition
Add Definition To Classification
Classification Scheme
Classes
Moose 1
Moose 2
Moose 3
Moose 4
Moose 5
Moose 6
Moose 7
Moose 8
Moose 9
Description
Definition
Edit
Remove
Load...
Save...
Other
Create Classification
Options
Cancel

New class name: Moose 10

Class description: Tenth moose class.

AgeClass=(0-20, 20-40, 60-80 OR 100-1

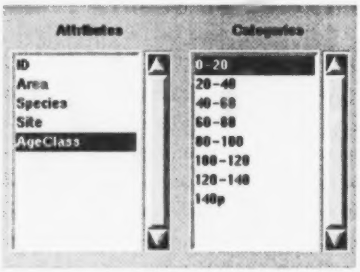
Description of Moose 1

(Species=(Pj) AND
Area < 30) OR
Site=(X)

Name: Moose 6

Desc: Description of moose 6

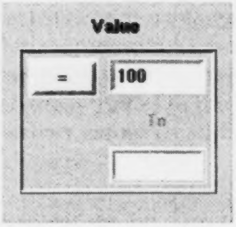
10.1.2 Creating a Class Definition


Attributes
ID
Area
Species
Site
AgeClass
Categories
0-20
20-40
40-60
60-80
80-100
100-120
120-140
140p

Enter the class name in the *New class name* entry. The class description is optional.

You can create classes using any combination of attributes listed in the *Attributes* list box. Clicking on an attribute will either bring up a list of available categories in the *Categories* list box (for *categorical* attributes) or enable the *Value* box (for *numeric* attributes).

For *categorical attributes,* select 1 or more categories by clicking on the category names. To select multiple categories, hold the **<Ctrl>** key while clicking on names. To add the attribute-category list to the class definition, click on ***And*** or ***Or***. For *numeric attributes,* click on the = button in the ***Value*** box to select the desired math operator and enter the desired value. To add the attribute-value expression to the definition, click on ***And*** or ***Or***.

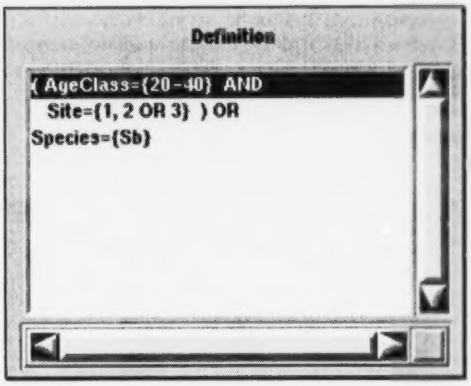


100

As you add definitions to the class, the ***Definitions*** list box will display them. Each definition occupies 1 line. To remove a definition, click on it and select ***Remove***.

Use the ***And*** or ***Or*** buttons to build *Boolean* expressions of attributes that define the class. To group a set of existing definitions, highlight them in the ***Definition*** list box, click on the ***(...)*** button and select the ***(...)>>*** option. LEAP II places grouped definitions in brackets and treats each as a single unit for the purpose of evaluating the expressions. To remove a grouping, highlight the previously grouped definitions and select the ***(...)<<*** option of the ***(...)*** button.

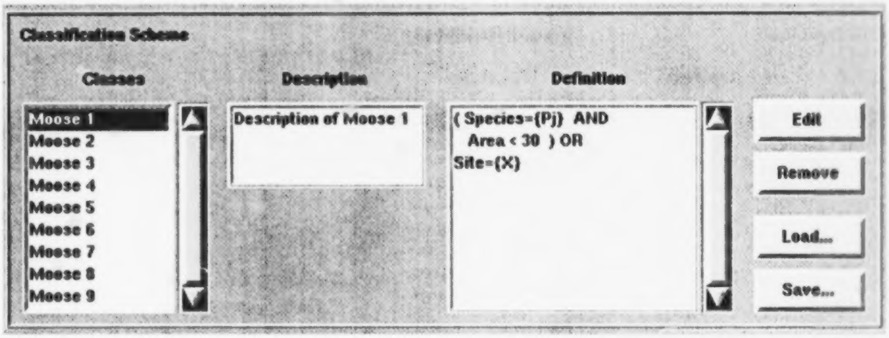
To add a complete class definition to the classification scheme, click on ***Add Definition To Classification***.



(AgeClass={20-40} AND
Site={1, 2 OR 3}) OR
Species={Sb}

10.1.3 Managing the Classification Scheme

The ***Classification Scheme*** box displays classes that are part of the classification scheme. To review the description and definition of any class in the scheme, click on its name in the ***Classes*** list box.



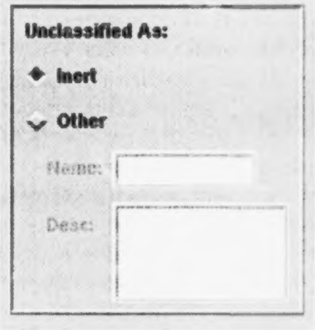
Moose 1
Moose 2
Moose 3
Moose 4
Moose 5
Moose 6
Moose 7
Moose 8
Moose 9

Description of Moose 1

(Species={Pj} AND
Area < 30) OR
Site={X}

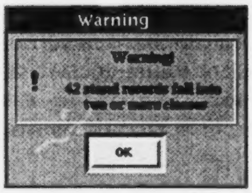
To edit a class definition, click on the class name and select ***Edit***. The class definition will move to the ***Define A New Class*** box, where you can modify it. To delete a class definition, click on the class name and select ***Remove***. To save the current classification scheme for future use, click on ***Save***. The ***File Cabinet*** will open, allowing you to specify a file name. To load a previously saved classification scheme into the current analyses, click on ***Load***.

Stands that don't fall into any classes of the classification scheme may be classed as inert or as another class. To classify these stands as inert, click on ***Inert***. Alternatively, click on ***Other*** and enter the class name and description. This class may already exist in the classification scheme or may be a new one.



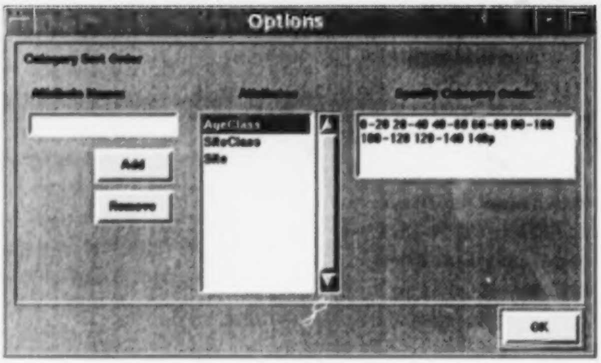
After you complete and save the classification scheme, click on ***Create Classification*** to implement the classification and generate the landscape(s). If the ***LEAP Logger*** is open, you can monitor the classification process (for more information on the ***Logger***, see Section 12.2). When the landscapes are complete, you may use the ***LEAP Viewer*** o view the landscape images (for more information on the ***Viewer***, see Section 12.3).

If any of the stands fall into 2 or more classes, LEAP II will display a warning message indicating the number of stands involved. Adjust your classification scheme to ensure that each stand falls into a single class. LEAP II classifies a stand *only once* (regardless of how many classes the stand actually matches), putting it into the first matching class in the **Classes** list.



10.1.4 Setting Classification Options

To set the classification options, click on ***Options***. The ***Options*** window will open, allowing you to specify the order in which the ***Categories*** list box displays categories of any categorical attribute (if not specified, the order of categories is based on their order in the data files). For example, ***Age Class*** might be re-ordered from ***41-60, 21-40***, and ***1-20*** to ***1-20, 21-40*** and ***41-60***. Changing the category display order is for convenience *only* and does not affect analysis results.



To set the category order for an attribute, enter the attribute name and click on ***Add***. Click on the name in the ***Attributes*** list box, then click on the ***Specify Category Order*** text box. Enter a space-delimited list of the categories in the desired order. The list may span more than 1 line.

To change the category order for a listed attribute, click on its name in the ***Attributes*** list box and edit the category list in the ***Specify Category Order*** text box. If you do not specify all categories for an attribute, LEAP II will first order those categories you do specify and then order the others based on their order in the data files. If you specify attributes or categories not found in the datasets, LEAP II will ignore them.

To remove an attribute from the ***Attributes*** list box, click on its name and select ***Remove***. To close the ***Options*** window, click on ***OK***. LEAP II automatically saves your specified sort order and will automatically recall it at your next session.

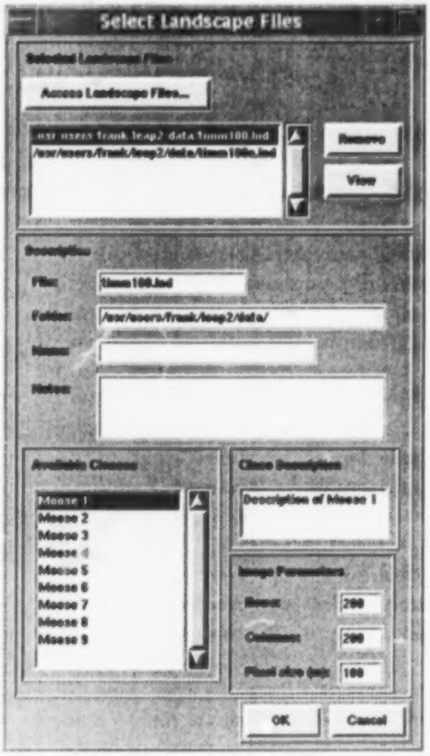
10.2 Selecting an Existing Landscape

To select 1 or more landscapes previously created using LEAP II, click on ***Select Landscape*** on the ***Main Window***. The ***Select Landscape Files*** window will open. Click on ***Access Landscape Files***. The ***File Cabinet*** will open; select 1 or more landscape files and then close the cabinet by clicking on ***OK***. The list box will display your selection(s).

To remove a landscape file from the list, click on its name and select ***Remove***. To view a landscape file, click on its name and select ***View***.

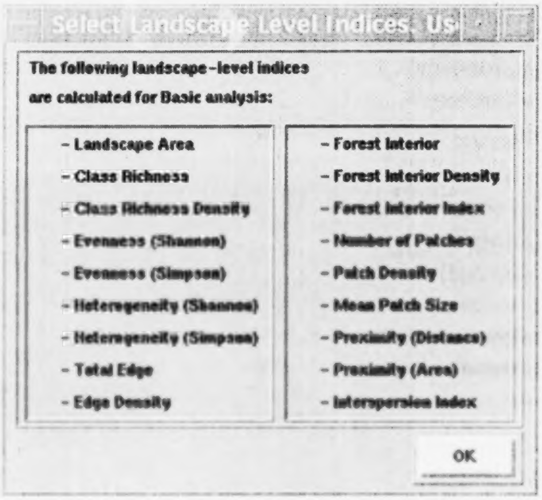
The ***Description*** box displays detailed information about the landscape highlighted in the list box. To view a class description, click on its name in the ***Available Classes*** list box.

When you have selected all of the landscape files you wish to analyze, click on ***OK*** to return to the ***Main Window***.



10.3 Selecting Indices for Analysis

After you have created or selected 1 or more landscapes, select the indices to calculate by clicking on *Select Indices* on the *Main Window*. A *Select Indices* window will open. This window identifies the indices that LEAP II will calculate. Its title and contents will vary, depending on the user level you selected in the *Session Setup*.


Select Landscape Level Indices: Us

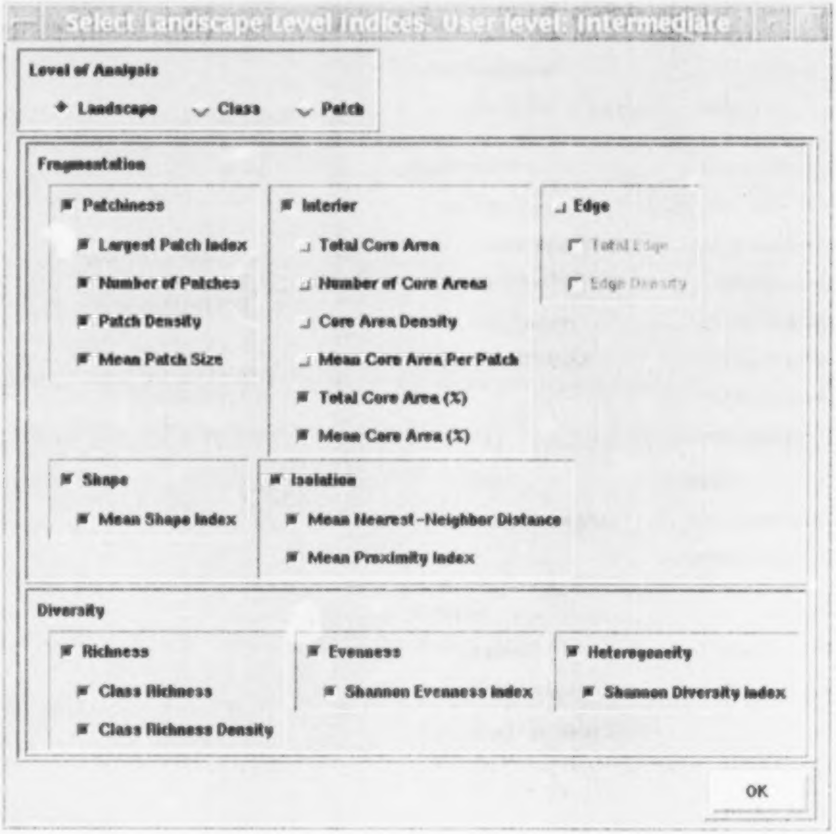
The following landscape-level indices are calculated for Basic analysis:

- Landscape Area
- Class Richness
- Class Richness Density
- Evenness (Shannon)
- Evenness (Simpson)
- Heterogeneity (Shannon)
- Heterogeneity (Simpson)
- Total Edge
- Edge Density
- Forest Interior
- Forest Interior Density
- Forest Interior Index
- Number of Patches
- Patch Density
- Mean Patch Size
- Proximity (Distance)
- Proximity (Area)
- Interspersion Index

At the *Basic* user level, the window will appear as at right. You cannot select indices to be calculated.

At the *Intermediate* or *Advanced* user level, the window will appear as below, and you *can* select indices.

The display is similar for both the *Intermediate* and *Advanced* user levels, but the *Advanced* level provides more indices.


Select Landscape Level Indices. User level: Intermediate

Level of Analysis

● Landscape ○ Class ○ Patch

Fragmentation

☑ Patchiness
- ☑ Largest Patch Index
- ☑ Number of Patches
- ☑ Patch Density
- ☑ Mean Patch Size

☑ Interior
- ☐ Total Core Area
- ☐ Number of Core Areas
- ☐ Core Area Density
- ☐ Mean Core Area Per Patch
- ☑ Total Core Area (%)
- ☑ Mean Core Area (%)

☐ Edge
- ☐ Total Edge
- ☐ Edge Density

☑ Shape
- ☑ Mean Shape Index

☑ Isolation
- ☑ Mean Nearest-Neighbor Distance
- ☑ Mean Proximity Index

Diversity

☑ Richness
- ☑ Class Richness
- ☑ Class Richness Density

☑ Evenness
- ☑ Shannon Evenness Index

☑ Heterogeneity
- ☑ Shannon Diversity Index

The *Select Indices* window groups the indices into 3 levels: *Landscape, Class,* and *Patch*.

To switch among these index levels, click on the corresponding option button.

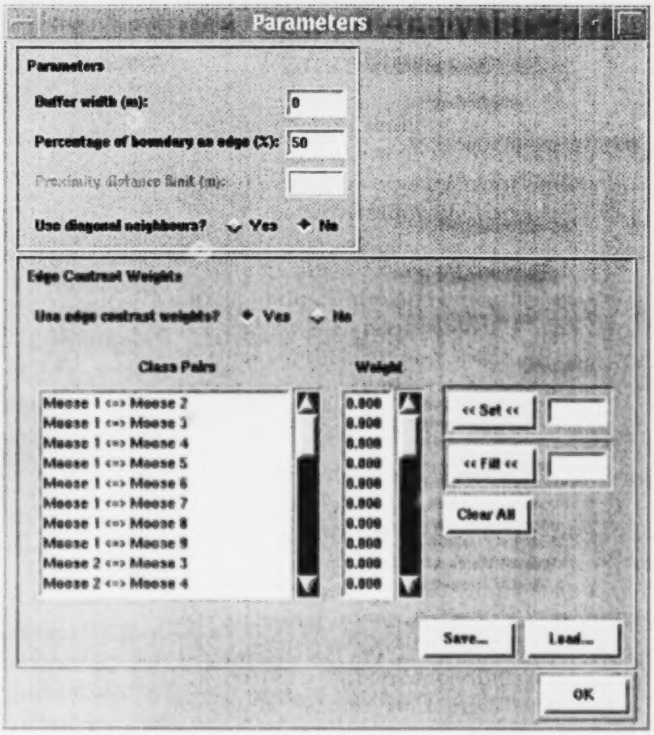
To toggle individual indices on or off, click on the corresponding index option button (e.g., *Largest Patch Index*).

To toggle entire groups of indices on or off, click on the index group option button (e.g., *Patchiness*).

To choose not to calculate any class or patch indices, select *No* at the *Calculate class indices* or *Calculate patch indices* prompts, respectively. The corresponding indices will not be calculated, which will decrease processing time.

When your selections are complete, click on *OK* to close the *Select Indices* window and return to the *Main Window*.

10.4 Setting Analysis Parameters



Parameters

Buffer width (m): 0

Percentage of boundary as edge (%): 50

Proximity distance limit (m):

Use diagonal neighbours? ○ Yes ● No

Edge Contrast Weights

Use edge contrast weights? ● Yes ○ No

Class Pairs	Weight
Moose 1 <=> Moose 2	0.000
Moose 1 <=> Moose 3	0.000
Moose 1 <=> Moose 4	0.000
Moose 1 <=> Moose 5	0.000
Moose 1 <=> Moose 6	0.000
Moose 1 <=> Moose 7	0.000
Moose 1 <=> Moose 8	0.000
Moose 1 <=> Moose 9	0.000
Moose 2 <=> Moose 3	0.000
Moose 2 <=> Moose 4	0.000

After selecting the indices, set parameters for the analysis by clicking on *Set Parameters* on the *Main Window*. The *Parameters* window will open.

To set a parameter, click on the corresponding entry and enter the desired value. To use diagonal neighbours, click on the *Yes* option button at the *Use diagonal neighbours* prompt.

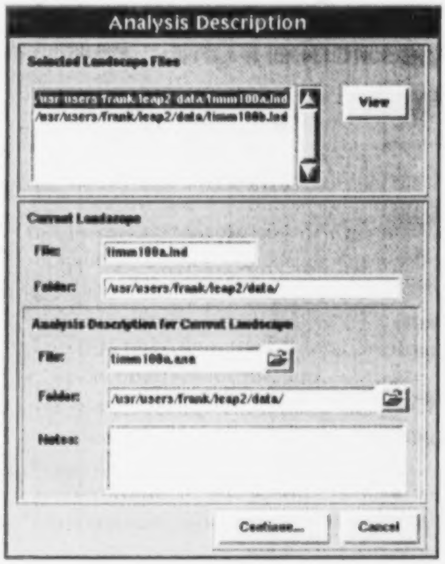
At the *Intermediate* and *Advanced* user levels, you can choose to use edge contrast weights by clicking on the *Yes* option button at the *Use edge contrast weights* prompt. The *Class Pairs* list box lists each unique pair of class names for the current landscape. The *Weight* list box indicates the corresponding edge weight for the pair. To change the weight for a given class pair, click on the pair name to highlight it. Click on the *Set* entry, enter the desired weight, and click on the *Set* button.

To set other class pairs to the same weight, double-click on the pair name. To clear all weight values, click on *Clear All*. To fill all empty weight values to the same value, click on the *Fill* entry, enter the desired weight, and click on the *Fill* button.

To save the edge weights for future analyses, click on *Save*. The *File Cabinet* will open, allowing you to specify a weight file name. To load previously saved weights into the current analyses, click on *Load*. You can only load weights created using the same class pairs as the current analysis.

When you have finished setting parameters, click on *OK* to close the *Parameter* window.

10.5 Calculating the Indices



Selected Landscape Files

/usr/users/frank/leap2/data/timm100a.lnd
/usr/users/frank/leap2/data/timm100b.lnd

Current Landscape

File: timm100a.lnd

Folder: /usr/users/frank/leap2/data/

Analysis Description for Current Landscape

File: timm100a.ana

Folder: /usr/users/frank/leap2/data/

Notes:

To run the analysis, click on *Calculate Indices* on the *Main Window*. The *Analysis Description* window will open, showing the list of selected landscape files. A separate file will be created for the analysis of each landscape in the list box. The *Analysis Description for Current Landscape* box displays the default file and folder name assigned to each analysis.

To change the default analysis file and folder names, click on the corresponding landscape name in the list box and enter your changes in the *File* and *Folder* entries. Enter descriptive notes about each analysis in the *Notes* entry.

To proceed with the analysis, click on *Continue*. If 1 or more of the specified analysis files already exists, LEAP II will prompt you to overwrite them. Click on *No* to return to the

Analysis Description window and rename the analysis file(s) or click on ***Yes*** to proceed with the analysis. A message window will open to indicate that the analysis is in progress. If the ***LEAP Logger*** is open, you can monitor the progress of the analysis. When the analysis is complete, you will be given the option of browsing the results; if you click on ***Yes***, the ***LEAP Browser*** will display the analysis.

10.6 Viewing the Analysis

If you choose not to view the analysis immediately, you may browse it any time later by clicking on ***View Analysis*** on the ***Main Window***. The ***LEAP Browser*** will start (if it is not already running) and will allow you to select any completed analysis for viewing (for more information on the ***Browser***, see Section 12.4).

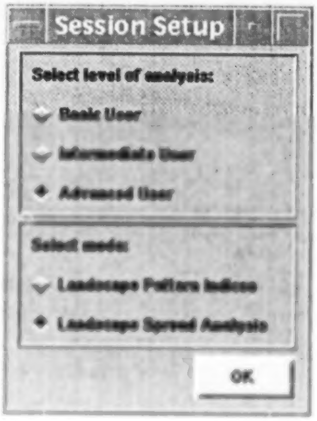
CHAPTER 11
Landscape Spread Analysis

To access LEAP II's *Landscape Spread Analysis,* click on *Session Setup* on the *Main Window.*

Select the *Advanced User* level of analysis and the *Landscape Spread Analysis* mode.

The configuration of the *Main Window* for the *Landscape Spread Analysis* (shown at right) differs slightly from the *Landscape Pattern Indices* configuration. However, as with the landscape pattern analysis (see Chapter 10), the buttons and their linkages indicate the steps involved in an analysis.

To begin, click on *Create Surface* or *Select Surface,* depending on whether you want to create a new friction surface or use an existing one.

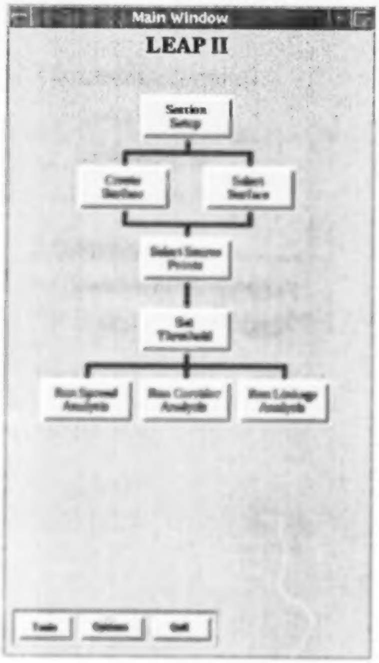

Session Setup

Select level of analysis:

○ Basic User
○ Intermediate User
● Advanced User

Select mode:

○ Landscape Pattern Indices
● Landscape Spread Analysis


Main Window
LEAP II
Session Setup
Create Surface
Select Surface
Select Source Points
Set Threshold
Run Spread Analysis
Run Corridor Analysis
Run Linkage Analysis

11.1 Creating a New Friction Surface

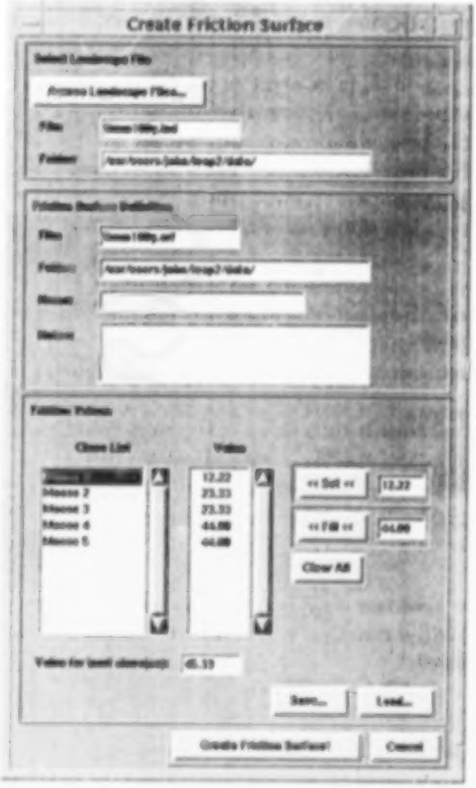
To create a new friction surface, click on *Create Surface* on the *Main Window.* The *Create Friction Surface* window will open, allowing you to select the landscape file that will be used to generate the friction surface. It also allows you to save the friction surface to a file and folder and to provide a descriptive name and notes.

To select a landscape file, click on *Access Landscape Files.* The *File Cabinet* will open; select a landscape file and close the cabinet by clicking on *OK.* The corresponding text boxes will display the file name and folder.

LEAP II will generate default file and folder names in the *Friction Surface Definition* box. You can change these names by editing the *File* and *Folder* entries and can add a descriptive name and notes in the *Name* and *Notes* entries.

When you select a landscape file, the *Class List* box displays any classifications associated with that landscape.

Each class in the *Class List* must be associated with a friction value. Specify this value in the *Value* list box.


Create Friction Surface
Class List
Value
<< Set <<
<< Fill <<
Clear All
Save...
Load...
Cancel

11.1.1 Specifying Friction Values

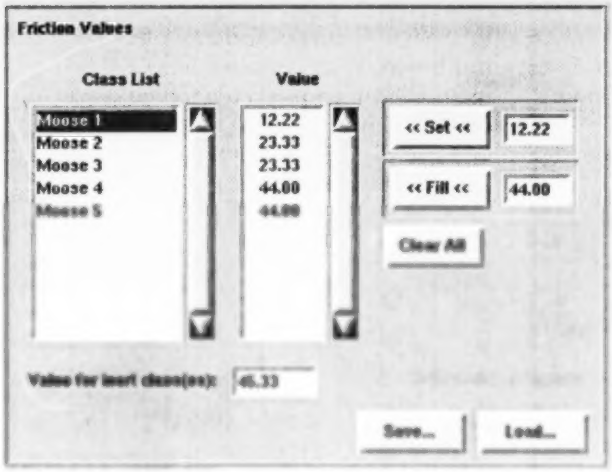
To specify the friction value for a given class, click on the class name in the *Class List*. Click on the *Set* entry, enter the desired value, and click on the *Set* button.

To set other classes to the same value, double-click on the class name.

To clear all friction values, click on *Clear All*.

To fill all empty values to the same value, click on the *Fill* entry, enter the desired weight, and click on the *Fill* button.

To specify friction values for the inert class of the landscape, enter the value at the *Value for inert class* prompt.


Friction Values
« Set «
« Fill «
Clear All
Save...
Load...

Class List	Value
Moose 1	12.22
Moose 2	23.33
Moose 3	23.33
Moose 4	44.00
Moose 5	44.00

Set: 12.22

Fill: 44.00

Value for inert class(es): 45.33

After you have specified the friction values, you can save them by clicking on *Save*.

To load a previously created friction classification list, click on *Load* and select the desired friction value file from the *File Cabinet*.

Click on *Create Friction Surface* to create the friction surface and return to the *Main Window*.

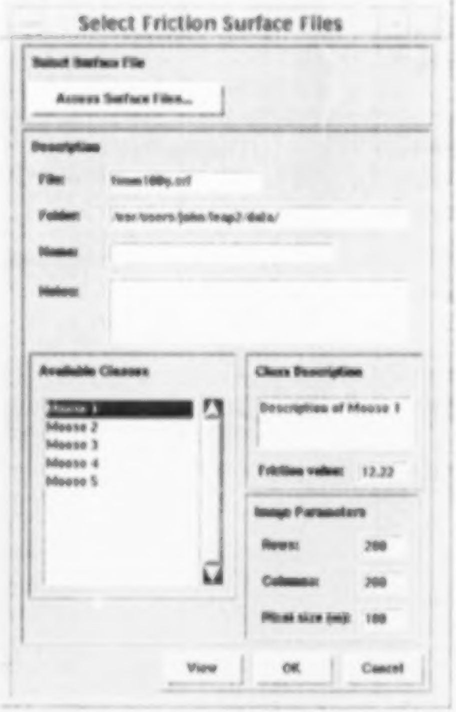
11.2 Selecting an Existing Friction Surface

To select an existing friction surface, click on *Select Surface* on the *Main Window*. The *Select Friction Surface Files* window will open, allowing you to select and view a friction surface file for analysis.

Click on *Access Surface Files* to open the *File Cabinet*. Select a friction surface file and close the cabinet. The corresponding entries will display the file and folder names. To view the file, click on *View*.

The *Description* box also displays detailed information about the selected friction surface file, such as image parameters and the available classes. To see a description and the friction value for a class, click on its name in the *Available Classes* list box.

Click on *OK* to close the *Select Friction Surface Files* window and return to the *Main Window*.


Select Friction Surface Files
Select Surface File
Access Surface Files...
Description
File:
Folder:
Name:
Notes:
Available Classes
Class Description
Image Parameters
View
OK
Cancel

Available Classes: Moose 1, Moose 2, Moose 3, Moose 4, Moose 5

Description of Moose 1

Friction value: 12.22

Rows: 200

Columns: 200

Pixel size (m): 100

11.3 Selecting Source Points

To select source points, click on ***Select Source Points*** on the ***Main Window***. The ***Select Source Points*** window will open, allowing you to select source points from a previously created source point file or to create a new set of points.

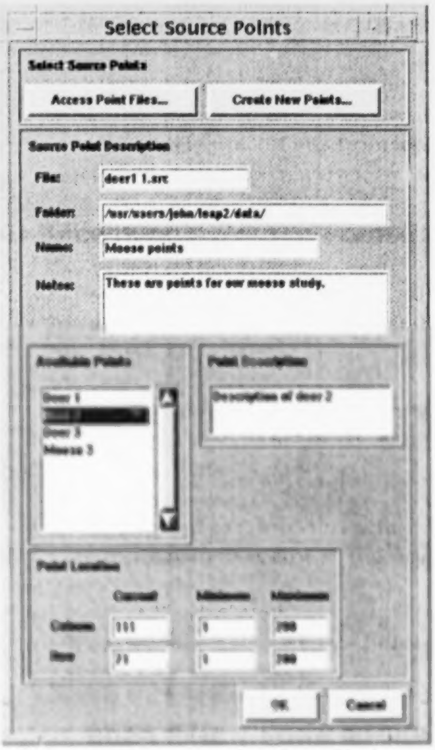
11.3.1 Accessing a Source Point File

To access a previously created source point file, click on ***Access Point Files*** to open the ***File Cabinet***. Select 1 source point file and close the cabinet.

The ***Source Point Description*** box will display the file's name, folder, and descriptive information in the corresponding text boxes.

To view the description and row and column location of an individual point, click on its name in the ***Available Points*** list box.

Click on ***OK*** to close the ***Select Source Points*** window and return to the ***Main Window***.


Select Source Points
Select Source Points
Access Point Files...
Create New Points...
Source Point Description
Available Points
Point Description
Point Location
OK
Cancel

File: deer1 1.src
Folder: /usr/users/john/leap2/data/
Name: Moose points
Notes: These are points for our moose study.

Available Points: Deer 1, Deer 2, Deer 3, Moose 3

Point Description: Description of deer 2

	Current	Minimum	Maximum
Column	111	1	200
Row	71	1	200

11.3.2 Creating a New Source Point File

To create a new source point file, click on ***Create New Points***. The ***Create Source Points*** window will open, allowing you to create and describe a new source point file.

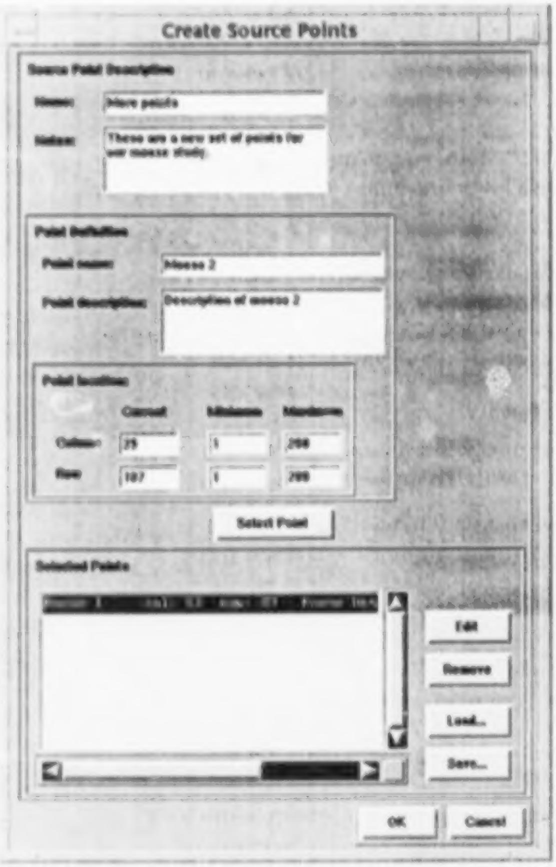
The ***Source Point Description*** box allows you to give the file a descriptive name and enter detailed notes about the source points.

The ***Point Definition*** box allows you to define each source point. Enter the point name and description in the ***Point name*** and ***Point description*** entries. Then specify the point location in 1 of 2 ways:

- Enter the point's column and row coordinates in the ***Point Location*** box, or
- Open the landscape image in the ***LEAP Viewer*** and select the desired point by double clicking on the image at the desired location. The corresponding row and column numbers will be placed in the ***Point Location*** box.

To help ensure that you specify a point within the landscape image, LEAP II displays the minimum and maximum allowable row and column values.

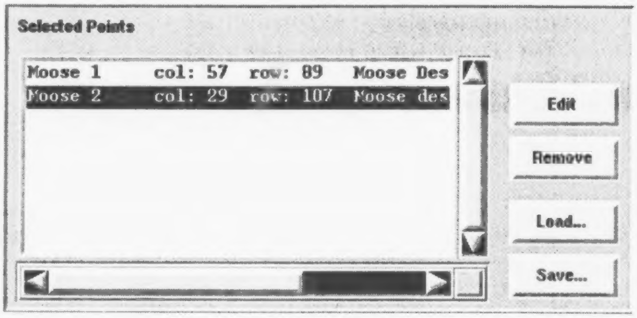
After you enter a point, click on ***Select Point***; the new point definition will appear in the ***Selected Points*** list box.


Create Source Points
Source Point Description
Point Definition
Point location
Select Point
Selected Points
Edit
Remove
Load...
Save...
OK
Cancel

Name: More points
Notes: These are a new set of points for our moose study.

Point name: Moose 2
Point description: Description of moose 2

	Current	Minimum	Maximum
Column	25	1	200
Row	107	1	200


Selected Points
Edit
Remove
Load...
Save...

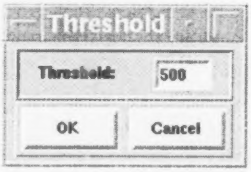
```
Moose 1     col: 57  row: 89   Moose Des
Moose 2     col: 29  row: 107  Moose des
```

To edit a source point, click on it in the *Selected Points* list box and select *Edit*. The point information will move back to the *Point Definition* box, where you can modify it.

To remove a point, click on it and select *Remove.*

To open a previously created source point file, click on *Load* to open the *File Cabinet*. Select 1 source point file and close the cabinet. To save the current set of points, click on *Save*. After you have entered all points, click on *OK*.

11.4 Setting the Threshold Value

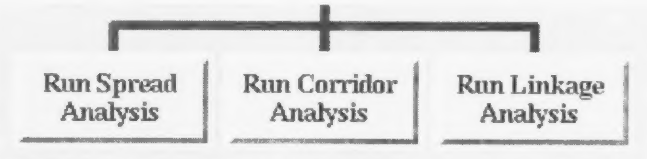

Threshold
OK
Cancel

Threshold: 500

To set the threshold for modelling, click on *Set Threshold* on the *Main Window*. The *Threshold* window will open.

Enter the desired value and click on *OK* to return to the *Main Window*.

11.5 Running the Models


Run Spread Analysis
Run Corridor Analysis
Run Linkage Analysis

To run the spread, corridor or linkage analysis, click on the corresponding button on the *Main Window*:

The *LEAP Viewer* will automatically display results of the analysis.

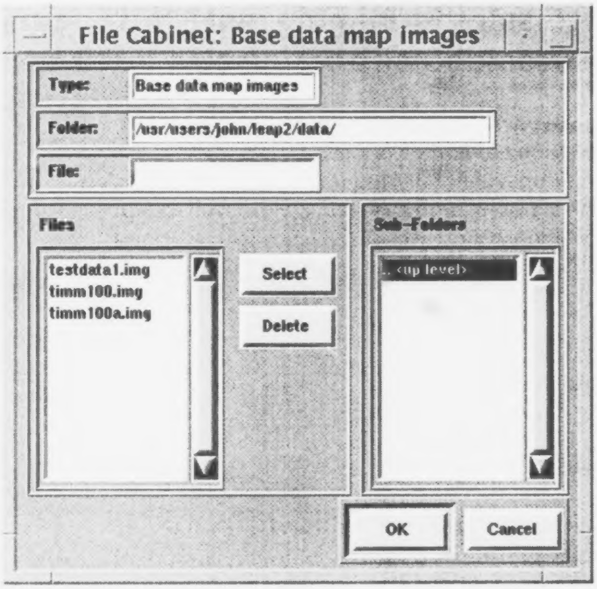
CHAPTER 12

LEAP Tools

LEAP II provides a number of tools to help you conduct an analysis: ***File Cabinet***, for selecting and managing files; ***LEAP Logger***, for monitoring the current session; ***LEAP Viewer***, for viewing base data, landscape, and friction surface map images; ***LEAP Browser***, for viewing analysis results; and ***LEAP Builder***, for creating LEAP II base datasets

LEAP II automatically starts some of these tools, such as the ***File Cabinet***, the ***LEAP Viewer***, and the ***LEAP Browser***, as needed. To start any of these tools yourself (except the ***File Cabinet***) click on ***Tools*** on the ***Main Window*** and select the tool you wish to use.

12.1 Managing LEAP Files: Using the File Cabinet



Type: Base data map images

Folder: /usr/users/john/leap2/data/

File:

Files:
testdata1.img
timm100.img
timm100a.img

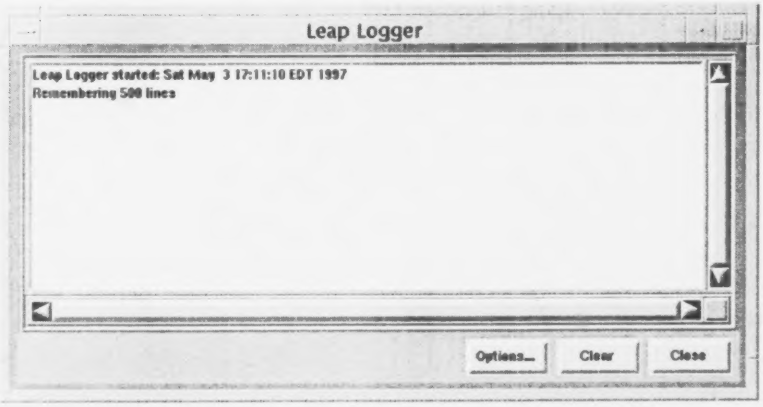
Sub-Folders:
<up level>

The ***File Cabinet*** provides a simple way to select the files you need to complete your analysis. It shows you only the files required for the current task. For example, if you are selecting a landscape, the ***File Cabinet*** will display only landscape files.

The ***Files*** box lists the files that exist in the current folder. To select a file, double-click on the file name; click on the file name and click on ***Select***; or enter the file name in the ***File*** entry. To delete a file, click on its name and select ***Delete***.

The ***Sub-Folders*** box lists sub-folders that exist in the current folder. To open a sub-folder, double click on its name. The ***Folder*** entry will display the name of the selected folder. To move up a folder, double-click on ***<up level>*** in the ***Sub-Folders*** list. After you select a file, click on ***OK*** to close the window.

12.2 Monitoring Your LEAP II Session: Using the LEAP Logger

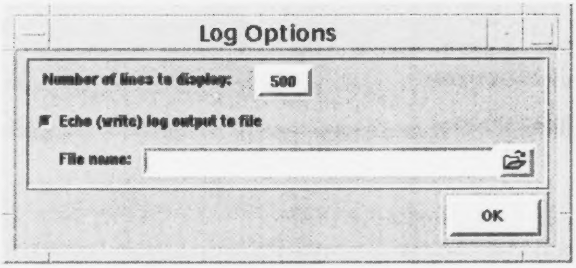


```
Leap Logger started: Sat May  3 17:11:10 EDT 1997
Remembering 500 lines
```

The ***LEAP Logger*** displays general information about the current session, including file selections, certain option settings, and current processing. It provides a record of the important steps of a session.

To start the ***Logger***, click on ***Tools*** on the ***Main Window*** and select ***LEAP Logger***.

To open the *Log Options* window, click on *Options* on the *LEAP Logger* window.


Log Options
Number of lines to display:
Echo (write) log output to file
File name:
OK

Number of lines to display: 500

☑ Echo (write) log output to file

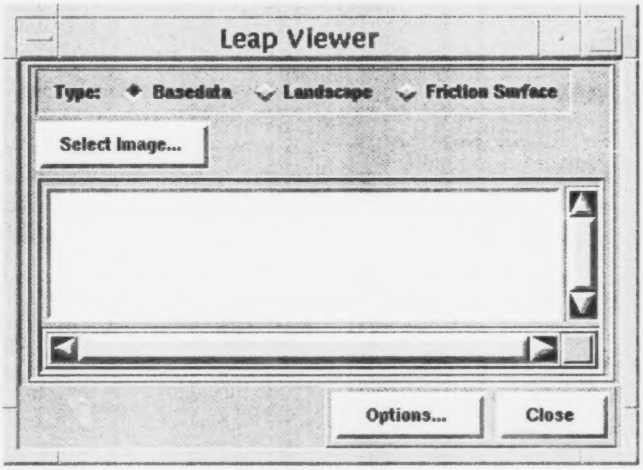
To select the maximum number of lines that will be displayed in the log window, click on the *Number of lines to display* button.

To save a permanent copy of the log to a file, click on *Echo log output to file* and enter the file name. Subsequent log output will be copied to that file. Click on *OK* to close the *Log Options* window.

To erase the current contents of the log window, click on *Clear* (this will not affect log output that is being echoed to a file). To close the *Logger*, click on *Close.*

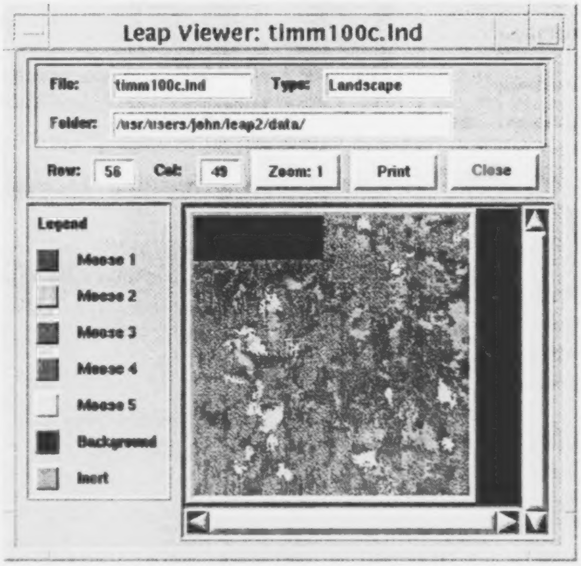
12.3 Viewing Map Images: Using the LEAP Viewer

The *LEAP Viewer* allows you to view all image data associated with your analysis, including base data, landscape, and friction surface images. Any time you choose to view an image, LEAP II will automatically start the *Viewer* (if it is not already running). You can also start the *Viewer* by clicking on *Tools* on the *Main Window* and selecting *LEAP Viewer*. The *Viewer* remains open until you close it or quit LEAP II.


Leap Viewer
Type:
Basedata
Landscape
Friction Surface
Select Image...
Options...
Close

Type: ◆ Basedata ◇ Landscape ◇ Friction Surface

To view an image, select the desired image type: *Base Data, Landscape,* or *Friction Surface*. Click *Select Image* to open the *File Cabinet,* select a file, and close the cabinet. The list box will display your image selection, and an *Image* window will open to display the image. You can select any number of images to view.


Leap Viewer: timm100c.lnd
File:
Type:
Folder:
Row:
Col:
Zoom: 1
Print
Close
Legend
Moose 1
Moose 2
Moose 3
Moose 4
Moose 5
Background
Inert

File: timm100c.lnd Type: Landscape

Folder: /usr/users/john/leap2/data/

Row: 56 Col: 49

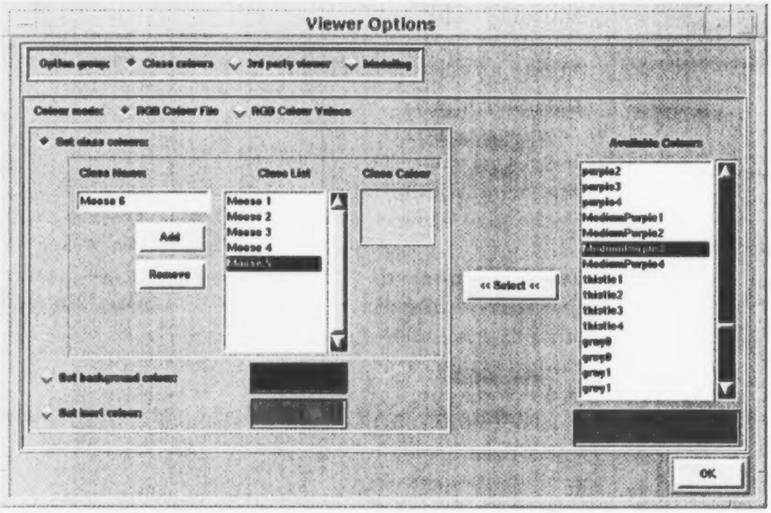
Clicking on the name of an image in the *Viewer* window will move its *Image* window to the top of the display screen. To minimize an *Image* window, double-click on its name. To retrieve a minimized image, click on its name again.

As you move the cursor over the image, the *Row* and *Col* entries display each point's row and column values. To adjust the zoom of the image by a factor of 1, 2, or 3, click on *Zoom*.

To print the image, click on *Print*. You can print the image to a postscript printer or create a postscript file. To close the current *Image* window, click on *Close*.

12.3.1 Setting Viewer Options

To open the *Viewer Options* window, click on *Options* on the *LEAP Viewer* window. Here you can adjust the landscape class colour scheme, choose a third-party viewer, and adjust modelling display parameters.

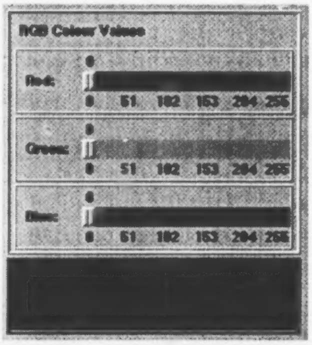

Viewer Options
Option group:
Class colours
3rd party viewer
Modelling
Colour mode:
RGB Colour File
RGB Colour Values
Set class colours:
Class Name:
Class List
Class Colour
Add
Remove
<< Select <<
Available Colours
Set background colour:
Set inert colour:
OK

Class Name: Moose 6

Class List: Moose 1, Moose 2, Moose 3, Moose 4, Moose 5

Available Colours: purple2, purple3, purple4, MediumPurple1, MediumPurple2, MediumPurple3, MediumPurple4, thistle1, thistle2, thistle3, thistle4, grey0, grey0, grey1, grey1

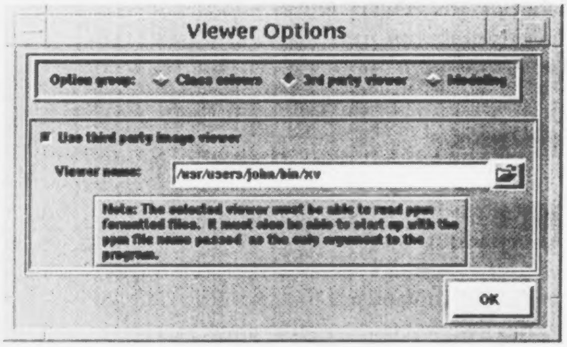
Setting the landscape class colour scheme: To customize the class colour scheme, click on the *Class colours* option in the *Option group* box. Choose either ***RGB Colour File*** or ***RGB Colour Values***. ***RGB Colour File*** provides a list of colours in the ***Available Colours*** list box. Click on a colour to display it in the colour box below the list. ***RGB Colour Values*** lets you select a colour by setting the colour's unique red, green, and blue (RGB) values (0 to 255) using sliders. The corresponding colour is displayed in the colour box below the sliders.


RGB Colour Values
Red:
0
0 51 102 153 204 255
Green:
0
0 51 102 153 204 255
Blue:
0
0 51 102 153 204 255

To set class colours, click on the ***Set class colours*** check box. Make a list of the classes for which you want to define colours. To add a name to the class list, enter the name in the ***Class Name*** entry and click on ***Add***. To remove a class from the list, click on the class name and click on ***Remove***. To assign the current colour to a class, click on the class name and click on ***Select***.

To set the colour for the background and the inert class, click on the corresponding check box and click on ***Select***. LEAP II automatically saves your colour selections.

Using a third party viewer: The ***LEAP Viewer*** lets you view images using other ***Viewer*** software packages. To select another viewer, click on ***3rd Party Viewer*** in the ***Option group*** box. Click on the ***Use third party image viewer*** check box. Enter the name of the viewing program in the ***Viewer name*** entry or click on the folder icon to open the ***File Cabinet*** and select the program.

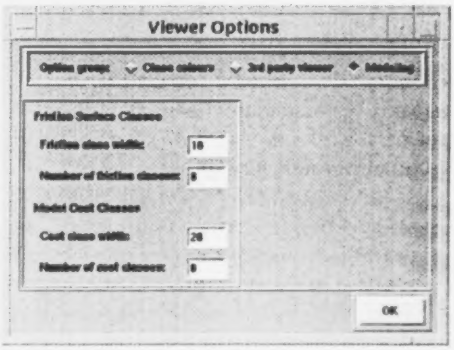

Viewer Options
Option group:
Class colours
3rd party viewer
Modelling
Use third party image viewer
Viewer name:
OK

Viewer name: /usr/users/john/bin/xv

Note: The selected viewer must be able to read ppm formatted files. It must also be able to start up with the ppm file name passed as the only argument to the program.

Setting spread model friction and cost display classes: For spread model images, you can adjust the classes by which friction and cost values are displayed. To set these options, click on ***Modelling*** in the ***Option group*** box.

Specify the number of friction and cost classes to be displayed in an image and the width of each class. These options affect the display of friction and cost surfaces but not the analysis.


Viewer Options
Option group:
Class colours
3rd party viewer
Modelling
Friction Surface Classes
Model Cost Classes
OK

Friction class width: 10

Number of friction classes: 8

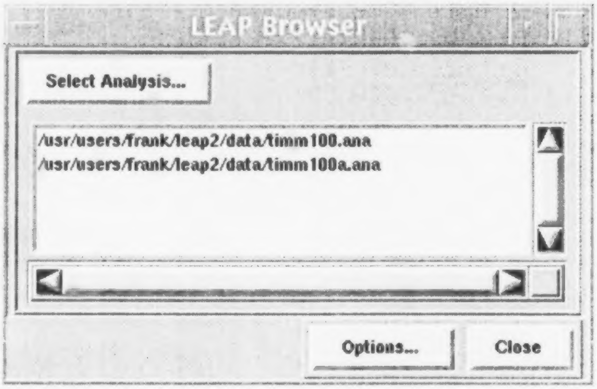
Cost class width: 20

Number of cost classes: 8

12.4 Viewing Analysis Results: Using the LEAP Browser

The ***LEAP Browser*** allows you to browse the results of analyses in tabular and graphical form. It can display current and existing analyses. Results of 2 or more analyses can be displayed in separate windows.

To start the ***LEAP Browser***, click on ***Tools*** on the ***Main Window*** and select ***LEAP Browser***. If you have carried out an analysis in the current session, you can also click on ***View Analysis*** on the ***Main Window***. The ***Browser*** will remain on screen until you close it or quit LEAP II.



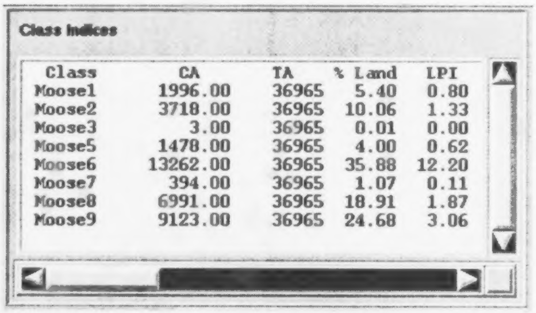
/usr/users/frank/leap2/data/timm100.ana
/usr/users/frank/leap2/data/timm100a.ana

The ***LEAP Browser*** window lists the analyses currently displayed on screen. To select an analysis for browsing, click on ***Select Analysis*** to open the ***File Cabinet*** and select an analysis file. Each time you select an analysis, it is added to the list in the ***Browser*** window.

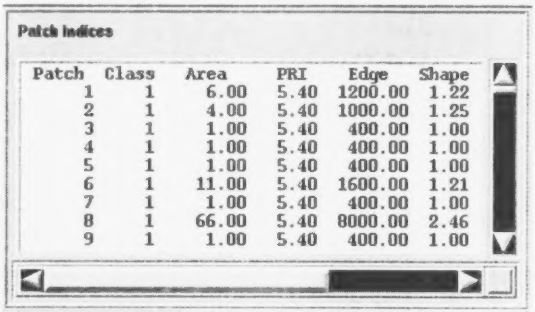
Each analysis that you open is displayed in its own ***Analysis*** window. The left side of each window displays details about the parameter settings of the analysis; the right side displays results of the analysis.

Clicking on the name of an analysis in the ***Browser*** window will move the ***Analysis*** window to the top of the display screen. Double-clicking on the name will minimize the ***Analysis*** window. To retrieve a minimized analysis, click on its name again.

By default, LEAP II displays landscape-level statistics when you first open an ***Analysis*** window. For ***Intermediate*** or ***Advanced*** analyses, you can toggle among landscape, class, and patch indices by clicking on the corresponding button. The ***Patch*** button will allow you to select either patch indices or patch area-class frequency distribution.


Class Indices

Class	CA	TA	% Land	LPI
Moose1	1996.00	36965	5.40	0.80
Moose2	3718.00	36965	10.06	1.33
Moose3	3.00	36965	0.01	0.00
Moose5	1478.00	36965	4.00	0.62
Moose6	13262.00	36965	35.88	12.20
Moose7	394.00	36965	1.07	0.11
Moose8	6991.00	36965	18.91	1.87
Moose9	9123.00	36965	24.68	3.06


Patch Indices

Patch	Class	Area	PRI	Edge	Shape
1	1	6.00	5.40	1200.00	1.22
2	1	4.00	5.40	1000.00	1.25
3	1	1.00	5.40	400.00	1.00
4	1	1.00	5.40	400.00	1.00
5	1	1.00	5.40	400.00	1.00
6	1	11.00	5.40	1600.00	1.21
7	1	1.00	5.40	400.00	1.00
8	1	66.00	5.40	8000.00	2.46
9	1	1.00	5.40	400.00	1.00

12.4.1 Saving and Printing Results

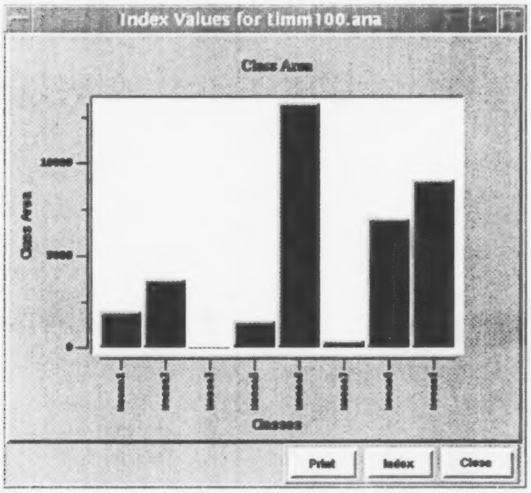
To save the results currently displayed in the ***Analysis*** window to an ASCII text file, click on ***File*** and select ***Write to file***. To print the results, click on ***File*** and select ***Print***.

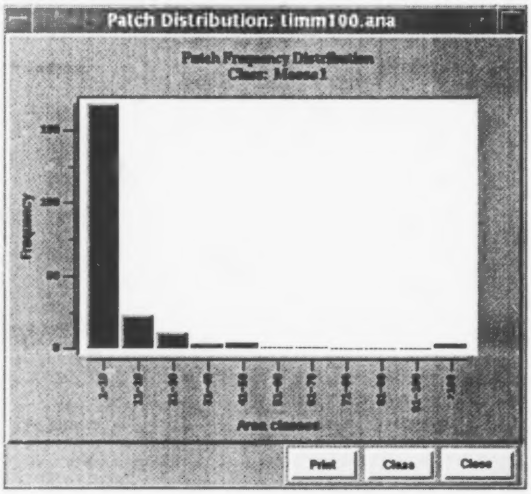
12.4.2 Graphing Results

To display bar chart graphs of the class indices or patch area-class frequency distribution, click on ***Graph*** and select ***Class indices*** or ***Patch frequency distribution***.

Class indices displays a bar chart for 1 index at a time. To change the index, click on ***Index*** and select from the list of available indices.

Patch frequency distribution displays a bar chart for 1 class at a time or for the total of all classes. To change the class, click on ***Class*** and select from the list of available classes. The last class in the list is always ***Total*** (the sum of all classes).


Index Values for timm100.ana
Class Area
Class Area
10000
5000
0
Classes
Print
Index
Close


Patch Distribution: timm100.ana
Patch Frequency Distribution
Frequency
0
Area classes
Print
Class
Close

To print a bar chart to a postscript file, click on ***Print*** and select ***Write to postscript file***; to print to a postscript printer, click on ***Print*** and select ***Print to postscript printer***.

To zoom in on any rectangular area of a bar chart, click on the left mouse button at 1 corner of the desired rectangle, move to the opposite corner of the rectangle, and click again. You can repeat the zoom any number of times.

To undo the last zoom, click the right mouse button. To close a ***Graph*** window, click on ***Close***.

12.4.3 Setting Browser Options

To set ***Browser*** options, click on ***Options*** on the ***Browser*** window. The ***Browser Options*** window will open. To adjust the patch area-class frequency distribution, specify the number of area classes and the class width to be used. Changes will affect subsequent displays.

12.4.4 Closing Browser Windows

To close an ***Analysis*** window, click on ***Close*** on that window. To close all ***Analysis*** windows and the ***LEAP Browser***, click on ***Close*** on the ***Browser*** window.

12.5 Constructing LEAP Datasets: Using the LEAP Builder

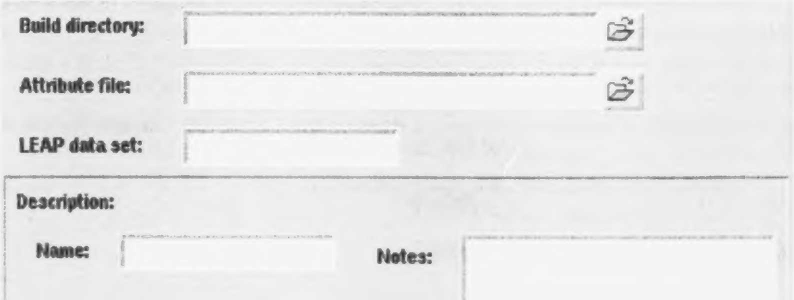
The ***LEAP Builder*** makes it easy to build LEAP II base datasets from ARC/Info coverages. You can store ARC/Info attribute data in many different ways using different internal (Info) and external databases (Oracle, Informix, etc.). In addition, you often need only a subset of attributes from a large set of attribute data (e.g., a forest inventory dataset) to generate classified landscapes. For these reasons, the ***LEAP Builder*** uses a simple comma-delimited ASCII file for attribute data. Some duplication of data results, but it allows you to build LEAP II base datasets with a minimal knowledge of ARC/Info and database processing.

The attribute file contains 2 basic components: 1 or more key fields and attribute fields. Each polygon in the base dataset must have a unique identifier that is contained in 1 key field or a combination of 2 fields. For example, a forest inventory database may contain stand numbers that are unique to 1 area of the dataset, such as a mapsheet. If the database will reflect only this mapsheet, then the stand number will serve as an appropriate key field. A dataset built over several mapsheets, however, may have duplicate stand numbers among the different mapsheets. To provide a unique identifier for each polygon, use a second field denoting the mapsheet number in combination with the stand number.

The attribute file that the ***LEAP Builder*** requires includes this key field or fields as well as fields for each of the attributes to be included in the base dataset. To construct this file, create a comma-delimited ASCII file with the key field(s) followed by each of the attribute columns that will be included in the base dataset. This process will vary depending on how the attributes are stored. If the attributes reside in the polygon attribute table of the coverage (.pat file) or another Info table, use the Tables module of Arc/Info to create the file with the Unload command. After entering Tables, select the .pat or Info table containing the attributes for the coverage. For .pat files, eliminate the world polygon (polygon that surrounds all of the polygons in the coverage) by reselecting the polygons with an area greater than 0 (the world polygon area is maintained as a negative value in .pat files).

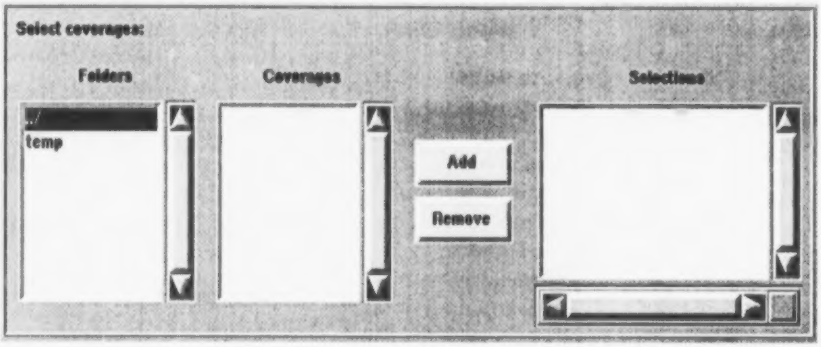
After you select all of the appropriate polygons, use the Unload command, specifying the key field(s) and the attributes to be placed in the base dataset. This will create a comma-delimited file of these fields. This process will vary depending on the database used to maintain the attribute data. Consult your database-package documentation for information about how to create comma-delimited ASCII files. If you use an external database, the associated coverage need not contain the attribute data, but it must contain the key field or fields specified in the LEAP II attribute file.

Be sure to note the order of the fields in the file and whether they are *character* or *numeric* fields. If a field contains any non-numeric characters, it must be specified as a character field. Purely numeric fields can be specified as either numeric or character. The choice depends on how you want LEAP II to use the field. Numeric attributes that are discrete or contain a fixed set of values are best specified as character fields because LEAP II will display these values for building classifications. A good example is a field containing numeric codes for 3 types of ownership of forest polygons. If this field is defined as a numeric field, classifications can be built using logical statements such as *greater-than* and *less-than*. Continuous data such as area, however, should always be specified as numeric, otherwise LEAP II will try to create and display a list of every unique value in the field.



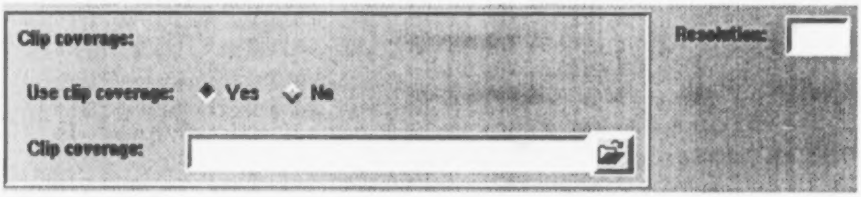
To start the ***Builder***, click on ***Tools*** on the ***Main Window*** and select ***LEAP Builder***. Enter the directory in which the base dataset is to be created in the ***Build directory*** entry or click on the folder icon to open the ***File Cabinet*** and select the directory. Enter the name of your attribute file in the ***Attribute file*** entry. Enter the name of the LEAP II data file you are creating in the ***LEAP data set*** entry (do not use capital letters when specifying the dataset). You can enter a descriptive name and notes in the ***Name*** and ***Notes*** entries.

In the ***Select Coverages*** box, select 1 or more coverages to use in making the base dataset. To navigate your set of folders, double-click on names in the *Folders* list box. When the desired coverage is displayed in the ***Coverages*** list box, click on it and click on *Add*.



You can select any number of coverages. Be sure that the attribute file specified earlier contains attributes for all of the coverages selected and that the structure of all coverages is identical. To remove a coverage from the ***Selections*** list, click on its name and select ***Remove***.

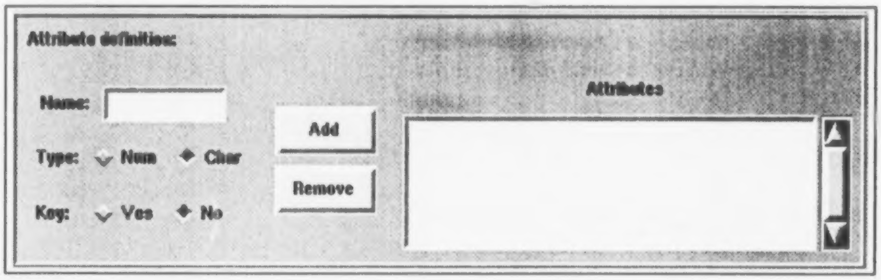
You can specify a clip coverage to trim the data to a specific area of concern such as a management unit of an ecological region. This coverage must be a simple coverage of this bounding unit alone. To use a clip coverage, click ***Yes*** at the ***Use clip coverage*** prompt, and enter the name of the coverage in the ***Clip coverage*** entry or click on the folder icon to select the coverage.



Use clip coverage: ● Yes ○ No

The resolution of the base dataset created from the coverage(s) is specified in the ***Resolution*** entry. Before making this choice, be sure you know the limitations of the dataset and the needs of the classifications that it must support.

In the ***Attributes definition*** box, enter the following information for each attribute: *Name*, *Type* (Num or Char), and whether it is a *Key* field (Yes or No). To enter a complete attribute definition into the ***Attributes*** list box, click on *Add*. You must enter the attributes in the exact order that they appear in the attribute file. The key field(s) must be named exactly as they appear in the .pat file of the coverage(s). You can name other attributes anything as long as you specify them in the same order as in the attribute file. To remove a definition from the list, click on the definition and select ***Remove***.



Type: ○ Num ● Char

Key: ○ Yes ● No

After you have entered all information, click on ***Continue*** to build the dataset.

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Appendix I

Installing LEAP II

LEAP II Distribution

LEAP II is distributed for Unix systems in a file named *leap2.tar.Z*. This file can be found on the FLEP anonymous FTP site. The IP number for the site is *142.140.196.67*; log on as *anonymous* and supply your e-mail address as the password. The distribution file is also available on 8 mm tape and on CD-ROM by request.

Included in the distribution is the file *README*. This file contains the most recent information about LEAP II as well as the LEAP II license agreement and copyright. Read this file before installing and using LEAP II.

LEAP II should be installed by the system administrator.

Where to Install LEAP II

If LEAP II will be used by a single person, you may install it on the file system in that user's account (e.g., */usr/users/mary/leap2*). If it will be used by several users on the same computer, you may install a single copy in a common area such as */usr/local/leap2*. Any number of users will then be able to use this single copy.

Installation Steps

- Copy the distribution file (*leap2.tar.Z*) to the directory where you wish to install LEAP II (e.g., */usr/users/mary*). The installation process will create a *leap2* subdirectory at that point. You should have *rwx* (read, write, execute) permission on the directory.
- Make that the current directory using the *cd* command (e.g., key in ***cd /usr/users/mary***).
- If a *leap2* subdirectory already exists in this directory, remove it and its contents (first move any files you wish to save somewhere else).
- Run the *umask* command and record the current value.
- Set *umask* to 022 (key in ***umask 022***).
- Uncompress the *leap2.tar.Z* file (key in ***uncompress leap2.tar.Z***).
- Extract the archive *leap2.tar* (key in ***tar xvf leap2.tar***). A *leap2* subdirectory will be created in the current directory (e.g., */usr/users/mary/leap2*). This subdirectory will contain all required files. A directory of sample files (*./leap2/sample*) and an empty work directory (*./leap2/work*) will also be created.
- Set *umask* back to its original value (e.g., key in ***umask 022***).
- Change directories to the *./leap2* subdirectory (key in ***cd leap2***).
- For the next steps, you will need *superuser* or *root* privilege, as some files will be copied to */usr/local/* subdirectories (key in ***su***, and enter the root password).
- Set *umask* to 022 (key in ***umask 022***).

- Extract the archive *graphics.tar* (key in ***tar xvf graphics.tar***). Some *blt*, *tcl*, and *tk* files will be installed in */usr/local/blt* and */usr/local/lib*. Some LEAP II-specific files will be installed in */usr/local/leap2*. You cannot change the destination of these files.
- Exit root (key in ***exit***).
- Edit the *leap2.config* file to reflect specified directories and file locations on your system.
- Copy *leap2.config* to the home directory of each user who will run LEAP II. The *work* directory (the *dir.work* parameter) specified in *leap2.config* must be unique for each user. For example, make Mary's work directory */usr/users/mary/work/* and make Sally's work directory */usr/users/sally/work/*. Edit each user's *leap2.config* file accordingly. Each user must have *read* and *write* access to his or her work directory; the directory must be created if it does not already exist (e.g., key in ***mkdir /usr/users/mary/work***).

Running LEAP II

Change directories to the *leap2* subdirectory (e.g., if LEAP II was installed in */usr/local/leap2*, key in ***cd /usr/local/leap2***). To start the program, key in *leap2* or *./leap2*.

You can also set up an *alias* to execute LEAP II regardless of the current directory. For example, if LEAP II is installed in the directory */usr/local/leap2*, key in ***alias leap2 /usr/local/leap2/leap2 &***. Then to start the program, key in ***leap2*** from any directory. The alias can be defined in the *.cshrc* or *.profile* file of the user, so that it is created automatically when the user logs in.

Sample Data

A sample dataset is included in the *./leap2/sample* directory:

- ***timm100.img***: 16-bit binary base data image
- ***timm100.dat***: corresponding stand data file
- ***timm100.hdr***: corresponding header file

Appendix II

Data File Format

Each LEAP II base dataset consists of the following files: raw binary image, stand data file, and header file. All 3 files must have the same base name and the file name extensions *.img*, *.hdr*, and *.dat*, for image, stand, and header file, respectively (for example, *kc100.img*, *kc100.dat* and *kc100.hdr).*

The binary image file contains the spatial data for the study area in a raw 16-bit (2-byte) or 32-bit (4-byte) binary format. Each value in the file represents a pixel in the image. The value of a pixel represents the stand number (or ID value) for the stand (or polygon) in which the pixel occurs. For example, a 16-bit image with 200 rows and 100 columns will have an image file with 20000 values and will be 40000 bytes in size. Values in the image file are specified by row and then column, starting at the top left of the image (e.g., the 202nd value in a 200 row x 100 column image file is for the pixel at row 3 column 2).

The stand data file is a text file that contains 1 line (record) for each stand in the image. Each column (field) in the file represents an attribute of the stand. Attributes may be numeric or character. ***One of these attributes must be the stand number or numeric ID value that corresponds to the values found in the binary image.***

The header file is a text file that defines the characteristics of the image and the attributes of the stand data file. For example:

```
# Sample header file for LEAP II
#
# Lines starting with '#' are treated as comments

# image type spec (must be 16_BIT_BINARY or 32_BIT_BINARY)
imagetype   16_BIT_BINARY

# image data specs
columns     200
rows        200
resolution  100

# field attributes of the data file
attribute   ID       n 96  4
attribute   Area     n 100 3
attribute   Species  c 18  2
attribute   Site     c 23  3
attribute   AgeClass c 27  7
```

Lines starting with # are comments that are ignored by LEAP II; *imagetype* must be *16_BIT_BINARY* or *32_BIT_BINARY*; *columns*, *rows*, and *resolution* refer to the dimensions and resolution of the image data file; resolution must be in metres.

For each attribute in the stand data file that will be used to build landscapes, include an attribute line. Each attribute line starts with the keyword *attribute* and is followed by the attribute name (do not embed spaces in attribute names), attribute type (*n* for numeric, *c* for character), the starting position of the attribute in the data file (in characters from the left margin), and the width of the attribute (in characters).

For example, the first 33 characters of the first few lines of the stand data file corresponding to the header file given above are as follows:

```
1149005330000140 Bw    2   80-100
1149005330000340 om   nf     0-20
1149005330000500 Po    2 100-120
1149005330000600 Pj    2    60-80
1149005330001020 Sb    1 120-140
1149005330001220 Bw    2   80-100
```

Note, for example, that *Species* starts at column 18 and is 2 columns wide; *AgeClass* starts at column 27 and is 7 columns wide.

Your stand data/header file **must** ***have a numeric attribute named*** **ID,** ***which uniquely numbers each stand in the file and corresponds to the values in the image file.***

Appendix III

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Copyright © 1997 Ontario Ministry of Natural Resources.

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Appendix IV

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LEAP II incorporates packages developed by other persons and organizations, specifically, tcl 7.6, tk 4.2, BLT 2.1, FRAGSTATS 2.0 and xgrabsc 2.3. Their copyright notices and/or terms of licence, where available, are included here.

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```
/*===========================================================================
 *
 * Name - cpyright.h
 *
 * Version:        1.6
 *
 * ccsid:  @(#)cpyright.h  1.6 - 04/26/93 17:44:24
 * from:  ccs/s.cpyright.h
 * date:  06/28/93 09:14:48
 *
 * Description: copyright information for xgrabsc
 *
 *===========================================================================
 *
 * Copyright (C) 1990-93 Bruce Schuchardt, Servio Corp.
 *
 * Permission to use, copy, modify, distribute, and sell this software
 * and its documentation for any purpose is hereby granted without fee,
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 * that both that copyright notice and this permission notice appear
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 * about the suitability of this software for any purpose. It is
 * provided "as is" without express or implied warranty.
 *
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 * INCLUDING ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS, IN
 * NO EVENT SHALL THE AUTHOR BE LIABLE FOR ANY SPECIAL, INDIRECT OR
 * CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS
 * OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE
 * OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE
 * USE OR PERFORMANCE OF THIS SOFTWARE.
 *
 * GetClientWindow() and TryChildren() functions in xgrabsc.c are
 * copyrighted by MIT:
 *
 *  Copyright 1989 by the Massachusetts Institute of Technology
 *
 *  Permission to use, copy, modify, and distribute this [XmuClientWindow]
 *  software and its
 *  documentation for any purpose and without fee is hereby granted, provided
 *  that the above copyright notice appear in all copies and that both that
 *  copyright notice and this permission notice appear in supporting
 *  documentation, and that the name of M.I.T. not be used in advertising
 *  or publicity pertaining to distribution of the software without specific,
 *  written prior permission. M.I.T. makes no representations about the
 *  suitability of this software for any purpose. It is provided "as is"
 *  without express or implied warranty.
 */
```

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